Hydrological Data for Lakes and Catchments in Muskoka/Haliburton (1978 – 2007)

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Hydrological Data for Lakes and Catchments In Muskoka/Haliburton (1978 - 2007)

Report prepared by:

Huaxia Yao
Monica Deveau
Lem Scott

Ontario Ministry of Environment
Dorset Environmental Science Centre
P.O. Box 39, 1026 Bellwood Acres Road
Dorset, Ontario, Canada P0A 1E0

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Preface

The Data Report Series is intended as an available source of basic data collected for lakes and watersheds in the Muskoka/Haliburton area of south-central Ontario. These data were collected as part of several Ministry of Environment (MOE) programs, including the Acid Precipitation in Ontario Study, the Lakeshore Capacity Study, and long-term environmental monitoring initiatives. These programs were initiated in the mid 1970s and continue to this day.

New programs to assess climate change impacts, water quantity/quality changes under multiple stressors have been started in recent years. The primary findings of these old and new studies have been and will continue to be summarized and published as data reports, technical reports and peer-reviewed articles.

This data report is a summary and initial analysis of hydrological and meteorological data collected from 1978 through 2007, for eight lakes and their watersheds in the Muskoka/Haliburton study area.

We thank Peter Dillon (Professor, Department of Chemistry, Trent University), Wolfgang Scheider (Manager, Water Monitoring and Reporting Section, MOE), Keith Somers (Site Supervisor and Biostatistician, DESC, MOE) and Jim Rusak (Biological Monitoring Scientist, DESC, MOE) for informative discussions and comments.

Table of Contents

List of Tables

List of Figures

1. Introduction 1
   - 1.1 Description of Study Area 1
   - 1.2 Methods 2
   - 1.3 Hydrometeorological Network 4

2. Runoff 5

3. Lake Evaporation 7
   - 3.1 Energy Budget 7
   - 3.1 Hamon Method 9

4. Annual Water Balances 10
   - 4.1 Supply Terms 12
   - 4.2 Loss Terms 13
   - 4.3 Water Balance Tables 14

5. Residence and Flushing Time for Study Lakes 15

6. Acknowledgements 16

7. References 17

Tables 1~18……...21~62

Figures 1~7……..63~108

Appendix A……109~180

Appendix B……181~206

List of Tables

Table 1 Area of gauged and ungauged sub-catchments, total area of all sub-catchments draining into a lake, lake area, total catchment area (the area controlled by the outflow gauging), and percentage of gauged area among the total area of all sub-catchments, for 8 study lakes. Area units are shown in m^2.

Table 2 Type and period of operation of hydrological structures used on gauged watersheds

Table 3 Stream flow duration patterns for the 28 gauged watersheds, 1978-2007 where data are available

Table 4 Hydro-Meteorological Station Identification

Table 5 Summary of meteorological and hydrological data for the Muskoka-Haliburton area

Table 6 Minimum, maximum and mean values of daily discharge (L/s) for 28 gauged watersheds, 1978-2007

Table 7 Total annual runoff (10^3 m^3/yr) for 28 gauged watersheds, 1978-2007

Table 8 Annual areal runoff (mm/yr) for 28 gauged watersheds, 1978-2007

Table 9 Minimum and maximum annual runoff (mm/yr) and their occurrence year, for the 28 gauged watersheds, 1978-2007

Table 10 Annual yield (ratio of runoff to precipitation) for 28 gauged watersheds, 1978-2007

Table 11 Minimum, maximum annual yield and their occurrence year, for the 28 gauged watersheds, 1978-2007

Table 12 Seasonal distribution of runoff from each stream watershed as a % for the 28 gauged watersheds, 1978-2007

Table 13 Monthly and annual summaries of precipitation (mm) in the Muskoka/Haliburton area

Table 14 Monthly and annual summaries of temperature (^{0} C) in the Muskoka/Haliburton area

Table 15 Annual lake evaporation (mm/yr) for eight study lakes, 1978-2007

Table 16 Annual change in lake level (mm yr^{-1}) for 8 study lakes, 1978-2007

Table 17 Annual water balances for 8 study lakes, 1978-2007

Table 18 Flushing rate and residence time (years) for eight study lakes, 1978-2007

List of Figures

Figure 1 Study area map, with locations of study lakes and meteorological sites

Figure 2 Lakes, their sub-catchments, and stream flow gauges

Figure 3 Muskoka/Haliburton Monthly Total Precipitation

Figure 4 Monthly lake evaporation (mm/month) for eight lakes, 1978-2007

Figure 5 Lake level gauge (m) for eight lakes, 1980-2002

Figure 6 Long-term trends in lake water balance terms

Figure 7 Annual residence and flushing time for eight lakes, 1978-2007

1. Introduction

The Dorset Environmental Science Centre has been studying small catchments and inland lakes in the Muskoka/Haliburton region of south central Ontario since 1976. A major component of these studies has been the development of mass balance models to predict the impact of environmental stressors on catchments and lakes in this area. Quantitative hydrological information is required to construct catchment and lake water balances, and is used as input to the chemical mass balance models. An earlier data report (Scheider et al. 1983b) presented data from the first four years of the study (1976 - 1980). Another more recent data report (Hutchinson et al. 1994) presented data for the following twelve years (1980-1992). This report presents basic hydrologic data from study watersheds for the period 1978 to 2007, covering both the old and new data sets, and provides updated or revised results of hydrological calculations.

1.1 Description of the Study Area

Eight catchments (Table 1) have been sampled and routinely monitored since 1976 for water chemistry and hydrologic components (Locke and Scott 1986, Girard and Reid 1990, Hutchinson et al. 1994). Each of the eight catchments includes a lake located in the lower part of the catchment (Figure 2). Within a catchment, there are one or more monitoring/sampling stations located on the streams (draining the sub-catchments into the lake), and there is a monitoring/sampling station on the outlet of the lake (controlling the whole catchment area).

Monitoring stations have different periods of operation, depending on their starting and ending dates (Table 2). The monitoring of these catchments currently includes twenty sub-catchments, two tributaries, and the eight outflows. In addition, hydrological and chemical flux information was measured on four additional streams (Twelve Mile South, Twelve Mile North, Beech Inflow One and Paint Inflow One) during the 1980s-1990s. These streams were chosen to further broaden the range of catchment types investigated. Meteorological data were collected at five regular stations from 1980 to 1984 (Reid and Dillon 1994). In 1984, the number of meteorological data collection stations was reduced to four (Locke and deGrosbois 1986), and these four stations have been in operation until the present (see location of the stations on Figure 1).

Two sub-catchments, Harp 4 and Plastic 1 (HP4 and PC1), have been studied on a more intensive level with many tributaries sampled throughout the sub-catchment. In addition, the hydrology of two tributaries, PC1-08 and HP4-21, has been measured since 1985 and 1987, respectively. The

percentage of watershed gauged varies from 19% to 87%, excluding Heney Lake catchment which was not monitored for stream inflows (Table 1). Detailed information on lake morphometry is found in Girard and Reid (1990) and sub-catchment physiography is described in Scheider et al. (1983b) and Girard et al. (1985).

Blue Chalk (BC), Red Chalk (RC) and Crosson (CN) lakes drain via the Black River into Lake Simcoe and ultimately into Georgian Bay via the Severn River. Harp (HP) Lake drains via the North Muskoka River into Lake Muskoka and then to Georgian Bay via the Moon River. The drainage of Dickie (DE), Heney (HY), Paint (PT) and Chub (CB) lakes is also into Georgian Bay via the South Muskoka River, Lake Muskoka and the Moon River. Plastic (PC), Twelve Mile (TW) and Beech (BE) Lakes drain into Lake Ontario at the Bay of Quinte via the Gull River, the Kawartha Lakes system and the Trent River.

A description of the bedrock and surficial geology underlying the study catchments is described in Jeffries and Snyder (1983) and Girard et al. (1985). Detailed geological information on the Harp 4 and Plastic 1 (HP4 and PC1) watersheds is described in Kirkwood and Nesbitt (1991) and Law (1991). Forest cover is typical northern hardwood mixed forest, consisting of maple, beech, yellow birch, hemlock, spruce and balsam fir. More detailed information is described in Lozano and Porton (1986). Significant beaver activity and the subsequent flooding have had a continuous influence on the hydrology and chemistry of stream catchments. Detailed information is available in Devito and Dillon (1993a) and Dahm et al. (1987). Urban development within sub-catchments has been limited. However, development around the shorelines of the lakes has increased significantly over the past 30 years. More detailed information on lakeshore development is described in Paterson et al. (2006).

1.2 Methods

The methods used in the collection of hydrological data were described in Locke and Scott (1986) and Hutchinson et al. (1994). The type and period of operation of hydrological structures used on study catchments vary, with the longer continuous operations occurred at three catchments (Harp, Dickie and Plastic; Table 2). Analysis of the hydrologic data, including estimation of mean daily flow for each of the sub-catchments and calculation of catchment water balances, was documented in Scott et al. (1994). The collection of meteorological data used in the catchment water balance calculations was described in Locke and deGrosbois (1986) and Hutchinson et al. (1993).

Methods used for calculating daily/monthly lake evaporation in this report are summarised in following Section 3, and methods used for calculating annual water balances of the lakes are summarized in Section 4.

Definitions

In order to facilitate the use of this report, the following conventions define some basic hydrologic terms relevant for data herein.

Watershed	The outer boundary around a catchment. The watershed is the point of elevation where flows divide. All points inside the boundary flow into the catchment, while no points outside the watershed flow into the catchment.
Catchment	The total spatial area within a watershed boundary.
Sub-catchment	The area drained by a single stream.
Stage (m)	The height of water measured above an established level or base at a gauging structure.
Discharge	The volume of water that passes a particular reference section in a unit of time.
Stage-discharge relationships	The relationship between the measured stage and the discharge of water from a stream at that point.
Lake Level	The gauge height reading corresponding to the lake level.
Mean Daily Discharge	An estimate of the mean daily flow from a sub-catchment through a calibrated gauging structure.
Perennial Stream	Describes a stream with a minimum mean daily discharge >0 for each year during the period 1978-2007. (Table 3 shows 3 of 28 study streams are classified as perennial.)

Intermittent Stream	Describes a stream that is dry for periods of every year during the period 1978-2007. The periodicity of flow for all study catchments (intermittent and perennial) as defined by Ward (1967) and described in Scheider et al. (1983a), is summarized in Table 9 for the 29 years of the study.
Residence Time	The length of time required to displace a volume of water equivalent to the lake volume. We calculate this term as lake volume divided by the total loss of water from the lake.
Flushing Time	Flushing time or replenishment rate is calculated as lake volume / lake outflow and is longer than the residence time because the water loss to evaporation is not included.

1.3 Hydrometeorologic Network

Gauging of streams within the Muskoka/Haliburton study area began in 1976. These sub-catchments were numerically identified from 1 - n with a lake specific alphabetic abbreviation included (e.g., HP3 = "HP" Harp Lake Catchment, "#3" sub-catchment). In only one circumstance is an outflow (Blue Chalk) considered an inlet to an adjacent catchment (Red Chalk). Numbers followed by an alphabetic code of A are not tributaries of adjacent sub-catchments. They represent additional sub-watershed delineations adjacent to previously defined sub-catchment areas. For example, HP3A is a separate sub-catchment adjacent to the sub-catchment HP3, not a tributary within the HP3.

The flow duration pattern of a stream can be divided into three types (see the definition of terms and Table 3). Most of our 28 streams monitored are neither intermittent (having a dry period in every year) nor perennial (never dry for all years).

Detailed description of the stream gauges and weather stations is provided in Table 4. Weather stations were established for the collection of meteorological parameters in representative catchments throughout the study area. From 1976 to 1984, fourteen stations were used; each station included a rain gauge and bulk precipitation collector (Locke and de Grosbois, 1986), but they were not regular or standard stations. Currently four regular stations are used to monitor meteorological parameters in the meteorological network throughout the study area. These stations are numerically identified 1 - n with a lake specific alphabetic abbreviation and type (e.g., HPP2 = "HP" Harp Lake, "P" Precipitation, "2" site number). The main station (also known as PT1P) was established in 1977 and was moved short distances (<1000 m) in 1978 and 1982 to its present location near to the Dorset Environmental Science Centre. This station has included a variety of different types of sensors and was maintained initially by the Canadian Centre for Inland Waters (CCIW) from 1976-1987. The Atmospheric Environment Service (AES) has also maintained a network of stations throughout the area.

Table 5 provides a summary of some of the meteorological parameters measured by these sites that strongly influence the hydrology in small headwater catchments.

2. Runoff

Runoff, as defined in Scheider et al. (1983b) with respect to the water balance equation for a lake, is water draining the terrestrial portion of a lake's catchment or drainage from upstream lakes. Operationally, it includes channelized stream flow measured at hydrological gauging stations. The type and period of use of each gauging station in the study area is summarized in Table 2.

The stage-discharge relationships for each sub-catchment are used to derive hourly stream discharges based on the monitored hourly data of stream stages. Hourly discharges are used to derive daily mean discharges for the stream or sub-catchment. The details of stage-discharge relationships are available in Hutchinson et al. (1994), and a new report on the relationship development, calibration and verification is forthcoming.

Daily mean discharges of 20 sub-catchments that drain into the eight lakes are available for 1978-2007 (Appendix A), as are the daily mean discharges of 8 outflow streams (Appendix B). The horizontal time span in figures is two hydrological years, with the hydrological year starting from June 1 of a year and ending at May 31 of the next year. For example, the two-year time span on the

first figure is June 1, 1978 to May 31, 1980. These daily discharges are the basic flow data used for the following summaries, analyses and calculations on stream flow characteristics or lake water balance.

The minimum, maximum and mean values of daily discharge for each stream and each year are summarized in Table 6. There are common patterns or similarities among the stream discharges, although there are exceptions. For all the 20 inlet streams draining to 8 lakes, the minimum daily discharge is close to zero for most monitored years as these streams are small, the maximum discharge varies in magnitude depending on stream size or watershed area, and the annual-mean discharge is much less than the maximum daily discharge. For all the 8 outflow streams, the minimum discharge is very small at 6 streams but is above zero at CN0 and RC0. The maximum discharge varies greatly between catchments, and the mean discharge is not so less than the maximum as is for inlet streams. Total annual discharge (10^3 m^3 yr^{-1}) is summarized in Table 7. The annual discharge in cubic meters varies and depends on the area of each catchment or sub-catchment.

Expressing annual discharge as aerial runoff (total annual discharge [m^3 yr^{-1}] / basin area [m^2]) factors out basin area and facilitates inter-basin comparison of annual discharge (Table 8). The annual runoff in mm/yr differs slightly among catchments because of spatial differences in precipitation, evapotranspiration and other hydrological conditions, and it differs largely among different years. Minimum and maximum annual aerial runoff from 1978-2007 are summarized in Table 9, and reveal that the extreme values may occur in different specific years between the catchments. The 1978-2007 mean runoff of all sites is 521 mm yr^{-1}, comparing well with the reported long term mean value of 400-500 mm yr^{-1} for the area (Anon. 1978).

Expressing unit runoff as yield (annual runoff [mm yr^{-1}] / annual precipitation depth [mm yr^{-1}]) further standardizes the annual discharge data. Yield is the fraction of the annual precipitation which is lost from the basin as streamflow, as summarized in Table 10. Annual 1978-2007 minimum and maximum yields by station are summarized in Table 11. The mean yield for the 1978-2007 period is 0.513 with mean values for the 28 individual watersheds ranging from 0.396 to 0.648.

Peak runoff occurs in March, April and May in response to snowmelt. Secondary peaks occur in October, November and December in response to increased precipitation and less interception by the terrestrial component. Residual runoff occurs in June, July and August due to terrestrial uptake and again in January and February as precipitation is stored as accumulated snow. The percentage of

annual flow that occurs in peak runoff periods ranged from 16.1 to 92.9 % with a mean value of 54.1 % (see Table 12). The percentage of annual flow occurring in secondary runoff periods ranged from 0.0 to 67.6 % with a mean value of 24.2 %.

3. Lake Evaporation

For each of the 8 lakes, daily evaporation rates are calculated by two methods: energy budget and Hamon equation, with the energy method covering the time from May 1 to November 15 and the Hamon method covering the remaining time in a year. The energy budget method was used for the study sites (Scheider et al., 1983a, 1983b), and was applied world-wide (Winter et al., 1995; Lenters et al., 2005; Yao, 2009). It requires lake temperature profile data from lake's surface to bottom which was monitored throughout the icefree period. The winter months without the data of lake temperature have much lower evaporation rates than in other months, and a simpler method like Hamon which only needs air temperature is able to give reasonable estimates of evaporation. The Hamon method is also widely applied in hydrological analyses (e.g. Yao and Creed, 2005). The two methods used for lake evaporation calculations are described below.

3.1 Energy Budget

The energy budget for a given lake and a time period between two lake-temperature-monitoring dates is calculated as

$$\lambda E = R_{net} + H_{sed} + A_{net} - H - S \qquad (1)$$

where all energy terms are in unit of Joules. λE is latent energy used by evaporation of lake water during that period (λ is the latent heat of vaporization (2.46×10^6 J kg^{-1}) and E is the evaporation (mm) within the period), R_{net} is net radiation, H_{sed} is heat released by lake sediments and (negligible for most cases), A_{net} is net heat advected into the lake from precipitation, inflows and outflows (also negligible), H is sensible heat transfer from lake surface to atmosphere, and S is the change of heat stored in the lake (due to temperature changes) during the period. The sensible heat term can be expressed as $H=B\cdot\lambda E$, where B is the mean Bowen ratio for the period and can be estimated from temperature. Removing the two negligible terms, equation (1) is rewritten as

$$E = \frac{R_{net} - S}{\lambda(1+B)} \quad (2)$$

The net radiation is an accumulation of daily net radiation in the period:

$$R_{net} = \sum_{i=1}^{n} [(1-\alpha_{sw}) r_{swd}(i) + (1-\alpha_{lw}) r_{lwd}(i) - r_{lwu}(i)] \quad (3)$$

where i is a day in the period ($i=1, 2, \ldots\ldots, n$ days), $r_{swd}(i)$ is daily downward shortwave radiation which is observed at the meteorological station, α_{sw}=0.07 is the shortwave albedo of water (value taken from Lenters et al., 2005), $r_{lwd}(i)$ is daily downward longwave radiation, α_{lw}=0.03 is the longwave albedo, and $r_{lwu}(i)$ is daily upward longwave radiation. Longwave radiation is calculated by $r_{lwd}(i)=\varepsilon_a \sigma T_a^4$, $r_{lwu}(i)=\varepsilon_s \sigma T_s^4$, where ε_a=0.91 and ε_s=0.97 are emissivity of the atmosphere and surface water respectively, T_a and T_s are daily air temperature and surface water temperature (in ˚K). The daily air temperature is provided by routine monitoring, while surface water temperature is observed only on the first and last day of a period (roughly 14-21 days long for the 8 lakes). The daily surface-water temperature is obtained by linear interpolation between the two days' values.

The heat storage change S in equation (2) is calculated by using vertical lake zones and lake temperature profiles. Temperature profiles are observed at the point in a lake where it has the deepest water. The water body is divided into vertical zones from lake surface to lake bottom, and the number of zones may differ a little among periods. The heat stored in the lake on the last and first day of the period is calculated, and their difference is the change in heat storage,

$$S = S2 - S1 = \frac{\rho_w c_w}{a_{s2}} \sum_{j=1}^{m_2} T_2(j) \cdot a_2(j) \cdot z_2(j) - \frac{\rho_w c_w}{a_{s1}} \sum_{j=1}^{m_1} T_1(j) \cdot a_1(j) \cdot z_1(j) \quad (4)$$

where $S2$ and $S1$ are heat storage on the last and first day respectively, ρ_w=1000 kg m^{-3} is water density, c_w=4186 J kg^{-1} ˚C^{-1} is specific heat of water, a_{s2} and $a_2(j)$ are the lake surface area and water area (m^2) of any zone j ($j=1, 2, \ldots\ldots, m_2$ starting from the lake surface zone) on the last day, $T_2(j)$ and $z_2(j)$ are the temperature and thickness of zone j on the last day. Similarly, a_{s1}, $a_1(j)$, $T_1(j)$, $z_1(j)$ are the surface area, water area, water temperature and zone thickness respectively on the first day. Water area a (m^2) at a height h (m) from lake bottom is estimated by an empirical relation derived from observed lake morphometry data [Reid et al., 1987]. For

example, the relation for Dickie Lake is expressed as

$$a = -389 \cdot h^3 + 10245 \cdot h^2 + 11592 \cdot h - 3340 \quad (5)$$

As in equation (6), the period-mean Bowen ratio B is calculated from daily Bowen ratios which are derived from air and lake surface temperatures [Chow et al., 1988].

$$B = \frac{\gamma}{n} \sum_{i=1}^{n} \frac{T_s(i) - T_a(i)}{e_{ss}(i) - e_{sa}(i)} \quad (6)$$

where γ is psychrometric constant (67 Pa $^{\circ}C^{-1}$), n is the number of days in a period, i is any day within a period, $T_s(i)$ and $T_a(i)$ are daily mean temperature ($^{\circ}C$) of lake surface and air above the lake respectively, $e_{ss}(i)$ and $e_{sa}(i)$ are saturated vapour pressure (Pa) at the lake surface and air temperatures. The saturated vapour pressure is calculated with the Arden Buck formula:

$$e_{sa} = 611.21 \cdot \exp[\frac{(18.678 - T_a / 234.5)T_a}{257.14 + T_a}] \quad (7)$$

Daily evaporation is not obtained by using equation (2) as the field collection of lake temperature profiles is not conducted every day in a period. After the total evaporation E is calculated as above, daily evaporation during the period is allocated from the total amount based on a distribution pattern. The Hamon method is the easiest way to estimate daily evaporation and uses only air temperature. Therefore, a time series of daily evaporation is created by using the Hamon method (described later), their summation gives a total evaporation, and the ratio of daily evaporation to total evaporation is determined. By applying the same ratios to the total evaporation value obtained from the energy budget method, daily evaporations for the energy budget method are obtained.

3.2 Hamon method

The Hamon method is often used to estimate lake evaporation or watershed potential evaporation because of its simplicity. For a given lake, daily evaporation e (mm) is calculated from daily temperature T_a ($^{\circ}C$) as follows.

$$e = 0.63 \cdot D^2 \cdot 10^{\frac{7.5T_a}{T_a+273}} \quad (8)$$

where D is the ratio of maximum sunshine duration (hour) to 12 hours, and is determined by latitude of the lake and the date:

$$D = \frac{1}{90}\arccos\{-\tan(\varphi)\cdot\tan[23.45°\sin(\frac{J-80}{365}\cdot 360°)]\} \quad (9)$$

where φ is the latitude (45.13˚ for Dickie Lake), J is the Julian day of any date of interest.

Total evaporation E in a period is the sum of daily evaporations of all included days.

4. Annual Water Balances

The lake water balance is an expression of the principle of conservation of mass. It assumes that the sum of water inputs to a catchment is equal to the sum of the outputs.
The model used for the period 1978 to 2007 is essentially the same as used by Scheider et al. (1983b). The annual water balance is described by:

$$\sum I_G + \sum I_U + P_{LA} + G_I = E + O \pm \Delta L + G_O \quad (10)$$

The inputs terms are: the sum of inflows from the gauged area of the watershed ($\sum I_G$), the sum of inputs from the ungauged areas ($\sum I_U$), the precipitation falling on the lake surface (P_{LA}) and the groundwater seepage into the lake (G_I). The loss terms are: the outflow (O), the change in lake storage or volume (Δ L), loss from the lake by evaporation (E) and groundwater loss from the lake (G_O). Note that the change in lake level is entered as a loss, but can be either positive or negative, depending upon whether water is added or removed over the time period for which the balance is calculated. It is assumed that the net inflow from ground water (G_I - G_O) to a lake on the Canadian Shield is negligible. This assumption was applied to the study area (Hutchinson et al., 1994; Devito and Dillon, 1993b) because of the shallow surficial till and largely impermeable bedrock in the Canadian Shield region, and is supported by some other studies in similar geological background (Hostetler and Bartlein, 1990; Grannemann et al, 2000; Yao, 2009).

Equation (10) can be rearranged to provide an estimate of the accuracy of the measured water balance for a catchment. This balance term is expressed as a percentage.

$$B = \frac{(O + E + \Delta L + G_O) - (\Sigma I_G + \Sigma I_U + P_{LA} + G_I)}{O + E + \Delta L + G_O} x\ 100\% \qquad (11)$$

The methods used to measure the components of the water balance have been described in Scheider et al. (1983b) and more recently in Hutchinson et al. (1994).

In computing these balances, each supply and loss term was measured or estimated individually and calculated on an annual basis, and described in detail in Sections 4.1 and 4.2. Water balances for all study catchments are described in Section 4.3.

Supply:

P_{LA} An estimated component expressed as direct contribution to the lake surface. The term is defined as lake area (m^2) x annual precipitation depth (m).

$\sum I_G$ A measured component expressed as m^3. Further definitions and application of this term may be found in Scott et al. (1994).

$\sum I_U$ An estimated component expressed as unmeasured terrestrial runoff. The term is defined as the sum of the measured inflows (m^3) / sum of their watershed areas (m^2) X the ungauged watershed areas (m^2).

G_I Groundwater is considered to be an unimportant component of the lake water balance. This is due to the impervious nature of the bedrock and the paucity of the surficial deposits in most of our study watersheds (Jeffries and Snyder 1983; also see the explanation on page 10).

Loss:

O A measured component expressed as m^3. Further definition and application of this term may be found in Scott et al. (1994). It is the outflow volume at the lake outlet.

E — An estimated component as defined and estimated in Section 3 in this report. It is a direct loss from the lake surface. The term is defined as lake area (m^2) X estimated evaporation rate (m).

ΔL — A measured component based on the hydrologic year further defined in Scheider et al. (1983b) and Scott et al. (1994). The term is defined as lake area (m^2) X measured loss (m).

G_O — As described in the supply side of this section, groundwater loss is considered to be unimportant.

4.1 Supply Terms

Precipitation

Daily precipitation depth was calculated at each meteorological station and used to estimate a Muskoka/Haliburton monthly precipitation depth (Figure 3). Table 13 summarizes the monthly and annual precipitation depths for 1978-2007. More detailed information on these calculations is available in Reid and Dillon (1994) and Hutchinson and Snell (1994). Annual amounts ($m^3\ yr^{-1}$) of precipitation falling on the lake surface is an input to the water balance and calculated as lake area (m^2) times annual depth of precipitation (mm). Annual precipitation depths (shown in Figure 3) ranged from 760 mm yr^{-1} (1997-1998) to 1276 mm yr^{-1} (1978-1979), with a mean of 1008 mm yr^{-1} (1978-2007). The wettest month (1978-2007) is usually November, with an average precipitation of 107.8 mm. February generally has the least amount of precipitation (61.5 on average), though there are some exceptional years.

Table 14 summarizes the monthly mean and annual mean temperature for the region. The hottest month is July (18.6 ^{0}C on average), the coldest month is January (-10.1 ^{0}C), with a 30-year mean temperature of 5.0 ^{0}C.

Mean Daily Discharge

Values of mean daily discharge (L/sec) have been computed for each study stream. Graphs showing daily discharge for all inlet sub-catchments over twenty-nine hydrologic years are presented in

Appendix A. Table 7 summarizes annual discharges for 1978-2007. More detailed information on these calculations is available in Scott et al. (1994). Annual discharge (m^3 yr^{-1}) of surface runoff is an input to the lake water balance and calculated as basin size (m^2) times surface runoff depth (m).

Unmeasured Terrestrial Runoff

It is assumed that the monthly or annual contributions from the ungauged sub-catchments will respond to atmospheric inputs similarly to that of the gauged sub-catchments within the same drainage basin. Therefore, the prorating method described to calculate this component (supply term $\sum I_U$) is assumed to be roughly correct (Devito and Dillon, 1993b).

The percent catchment area unmeasured ranged from 13% at Crosson to 100% at Heney. In a situation where a significant percentage of the catchment is ungauged (Heney and Blue Chalk), nearby catchments with similar catchment characteristics were used to do the prorating estimation. The estimations of unmeasured terrestrial runoff are summarized in Table 17.

Groundwater

Groundwater was previously described in Scheider et al. (1983b) as a component of unlikely importance. Further studies of groundwater and its significance in the water balance have shown that unless deep till is present, this component is negligible.

4.2 Loss Terms

Mean Daily Discharge from Outlets

The hydrograph plots of mean daily discharge for study lake outlets are presented in Appendix B.

Lake Evaporation

Annual lake evaporation (mm yr^{-1}) is summarized in Table 15, based on daily evaporation results that are obtained from the evaporation methods described above. Eight-lake-mean annual values ranged from 432 mm yr^{-1} in 2000-2001 to 670 mm yr^{-1} in 2005-2006. The 1978-2007 average value is 565 mm yr^{-1}. Annual evaporation loss does not differ much among the eight lakes.

Monthly lake evaporation for each study lake is plotted in Figure 4. Peak values (usually >100 mm month^{-1}) are most commonly observed in July for all lakes.

Lake Levels (Storage)

No measurements were made of soil/ground water storage in the terrestrial component of the catchment. Lake level gauges were in place for the 1980-2002 study period, excluding Crosson and Heney, in which level gauges were installed in 1982. Level gauges are referenced to a bench mark each year which is not related to area geodetic survey. Shift deviations in gauge elevation are referenced to the original data and weekly readings are adjusted accordingly. The bottom of the staff gauge is given an arbitrary value of 1.0 m which ensures positive readings should the lake level recede below the gauge. The components of the measurement of lake level can be found in Hutchinson et al. (1994). Measurements are taken on each site visit and are used to detect change in lake storage rather than absolute elevation. Changes in lake level are plotted in Figure 5 and summarized on an annual basis in Table 16. Annual lake level changes are generally small, ranging from -657 mm to 277 mm. Over the 29 years of this study period, mean changes in lake levels ranged from -44 mm to 8 mm in the 8 study lakes. Artificial control of lake levels does not occur on any of our study lakes.

4.3 Water Balance Tables

The terms of the water balance are described at the beginning of Section 4. The individual supply and loss terms, total supply and total loss, and resulting balance are shown in Table 17, for each of eight lakes and for each hydrological year. The balance term (or error/residual created in balance calculation) is expressed as the difference between annual loss volume and supply volume. Almost all annual budgets (loss and supply) balance to within 10%. The 29-year mean balance is 5.1%, 1.5%, 2.5%, 0.0%, -2.0%, -1.8% -2.8% and 2.6% respectively for Blue Chalk, Chub, Crosson, Dickie, Harp, Heney, Plastic and Red Chalk lakes. The overall average total supply (averaged over the 8 lakes and 29 years) is 400.7 million m^3 a year, the overall average loss is 403.0 million m^3, and their balance or residual is 2.3 million m^3, representing a tiny 0.2% of the total loss.

Terrestrial runoff supplies most of the water (excluding Blue Chalk - 48%) to the lake. The mean percentage of runoff (or inflow to lake) in total supply is 79, 83, 68, 78, 63, 60 and 83 % respectively for Chub, Crosson, Dickie, Harp, Heney, Plastic and Red Chalk lakes. Precipitation directly to the lake surface correspondingly contributes 21, 17, 32, 22, 37, 40 and 17 %, while it contributes 52% to

Blue Chalk. Loss via outflow is the most significant export in all lakes. The percentage of outflow in annual loss is 73, 88, 90, 82, 88, 79, 77 and 91 % respectively for Blue Chalk, Chub, Crosson, Dickie, Harp, Heney, Plastic and Red Chalk lakes. The evaporation percentage is 27, 12, 9, 17, 12, 21, 23, and 9 % respectively. Another water balance component, lake storage change, represents very little in the annual water balance.

A dataset as long as 29 years presents an opportunity to illustrate whether there are any trends or patterns in the water balance terms. The annual balance terms of three lakes, Dickie, Harp and Plastic having the longest data records, are illustrated in Figure 6. The dotted P, I, O and E represent annual precipitation, inflow into lake, outflow and evaporation from lake (in unit of m^3), and the linear lines represent long-term trends. They show similar trends. The runoff or inflow I and outflow O have a decreasing trend, precipitation decreases, while evaporation does not show an obvious change. Because of the decrease in precipitation over the catchment, runoff generated on the catchment has decreased too. And the decreased runoff has caused the decrease in lake outflow.

5. Residence and Flushing Time for Study Lakes

Flushing time is calculated as lake volume / lake outflow and is longer than residence time because the water loss to evaporation is not included. Annual values ranged from 1.07 years at Heney Lake to 16.63 years at Blue Chalk Lake.

Residence time is calculated as lake volume/total loss of water from the lake. Annual values ranged from 0.92 years at Heney Lake to 7.07 years at Blue Chalk Lake.

Residence and flushing times for the eight study lakes are plotted in Figure 7 and summarized in Table 18. Definitions of these terms are given in the Section 1.2 of this report.

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Table 1 Area of gauged and ungauged sub-catchments, total area of all sub-catchments draining into a lake, lake area, total catchment area (the area controlled by the outflow gauging), and percentage of gauged area among the total area of all sub-catchments, for 8 study lakes. Area units are shown in m^2.

Lake	Station	Area of Gauged Sub-catchments	Area of Ungauged Sub-catchments	Total Area of Subcatchments	Lake Area	Total Catchment Area	% Gauged among Total Area
Blue Chalk	BC1	204300					
	BC0		855000	1059300	523500	1582800	19.3
Chub	CB1	596900					
	CB2	1260000					
	CB0		861500	2718400	344100	3062500	68.3
Crosson	CN1	4562700					
	CN0		654800	5217500	567400	5784900	87.4
Dickie	DE5	299800					
	DE6	218000					
	DE8	669600					
	DE10	788900					
	DE11	762700					
	DE0		1325200	4064200	936000	5000200	67.4
Harp	HP3	260000					
	HP3A	196500					
	HP4	1190900					
	HP4_21	41200					
	HP5	1905300					
	HP6	99700					
	HP6A	152800					
	HP0		901400	4706600	713800	5420400	80.9
Heney	HY0		716600	0	213700	930300	0.0
Plastic	PC1	233400					
	PC1_08	34500					
	PC0		721600	955000	321400	1276400	24.4
Red Chalk	RC1	1335800					
	RC2	269600					
	RC3	704900					
	RC4	454600					
	RC0		975900	5323600	571300	5894900	81.7

Table 2 Type and period of operation of hydrological structures used on gauged watersheds

Watershed	Period of Operation		Hydrological Gauging Structure
BC0	16-Oct-80	31-May-01	Parshall flume with low flow structure
BC1	19-Nov-80	31-May-94	90 degree V-notch weir
CB0	01-May-76	30-Sep-80	120 degree V-notch weir
	12-Nov-80	31-Aug-01	Parshall flume with low flow structure
CB1	01-Jun-76	31-Aug-80	90 degree V-notch weir
	18-Nov-80	31-Aug-01	90 degree V-notch weir
CB2	16-Aug-77	30-Sep-80	Cippoletti weir with low flow structure
	15-Sep-81	31-May-01	Parshall flume with low flow structure
CN0	11-Dec-80	31-May-93	Parshall flume with low flow structure
CN1	31-Aug-81	31-May-93	Parshall flume with low flow structure
DE0	28-Aug-79	11-Sep-90	H flume with 90 degree V-notch
	24-Sep-90	23-Apr-03	Parshall flume with low flow structure
	23-Mar-04	present	Flume with low flow structure
DE5	10-Sep-81	25-Mar-03	Parshall flume with low flow structure
	11-Nov-03	present	Flume with low flow structure
DE6	14-Aug-79	03-Aug-03	90 degree V-notch weir
	21-Nov-03	present	90 degree V-notch weir
DE8	14-Aug-79	19-Aug-81	H flume with 90 degree V-notch
	25-Aug-81	02-Aug-03	Parshall flume with low flow structure
	02-Oct-03	present	Flume with low flow structure
DE10	14-Aug-79	31-Jul-03	90 degree V-notch weir and rectangular weir
	21-Nov-03	present	Flume with low flow structure
DE11	05-Oct-79	30-Dec-02	120 degree V-notch weir
HP0	24-Feb-81	20-Jun-03	Parshall flume with low flow structure
	03-Jul-03	present	Flume with low flow structure
HP3	12-Sep-79	01-May-03	90 degree V-notch weir
	02-Oct-03	present	90 degree V-notch weir
HP3A	26-Sep-79	02-Sep-03	90 degree V-notch weir and rectangular weir
	14-Oct-03	present	90 degree V-notch weir and rectangular weir
HP4	03-Jun-81	16-Apr-04	Parshall flume with low flow structure
	08-Sep-04	present	Flume with low flow structure
HP4_21	13-Oct-87	present	90 degree V-notch weir
HP5	15-Aug-79	27-Nov-02	Parshall flume with low flow structure
HP6	01-Sep-76	31-Oct-80	90 degree V-notch weir
	03-Jun-81	10-Aug-03	90 degree V-notch weir
	14-Oct-03	present	90 degree V-notch weir
HP6A	03-Jun-81	present	90 degree V-notch weir
HY0	03-Sep-81	31-May-93	Parshall flume with low flow structure
PC0	04-Oct-79	23-Jul-03	Parshall flume with low flow structure
	06-Nov-03	present	Flume with low flow structure

PC1	04-Oct-79	14-Aug-03	90 degree V-notch weir and rectangular weir
	21-Sep-04	present	90 degree V-notch weir and rectangular weir
PC1_08	22-Oct-85	present	90 degree V-notch weir
RC0	05-Dec-79	24-Oct-83	Parshall flume with low flow structure
	30-Nov-83	31-Aug-01	Parshall flume with low flow structure
RC1	18-Sep-80	31-Aug-01	Parshall flume with low flow structure
RC2	27-Nov-80	31-aug-01	90 degree V-notch weir
RC3	16-Jun-78	31-Oct-80	120 degree V-notch weir
	22-Sep-81	26-Aug-91	Parshall flume with low flow structure
	30-Oct-91	31-Aug-01	Parshall flume with low flow structure
RC4	01-Jun-76	31-Oct-80	120 degree V-notch weir
	22-Sep-81	31-Aug-01	Parshall flume with low flow structure

Table 3 Stream flow duration patterns for the 28 gauged watersheds, 1978-2007 where data are available

Watershed	Intermittent Streams	Perennial	Perennial/Intermittent
BC0			x
BC1			x
CB0			x
CB1			x
CB2			x
CN0		x	
CN1			x
DE0			x
DE5			x
DE6			x
DE8			x
DE10			x
DE11			x
HP0			x
HP3			x
HP3A			x
HP4			x
HP5			x
HP6			x
HP6A			x
HY0			x
PC0			x
PC1			x
RC0			x
RC1			x
RC2			x
RC3		x	
RC4		x	

There is no intermittent stream where there are some zero-discharge days in each year.

There are three perennial streams where the discharge is always larger than zero in all years counted.

Most of the 28 streams are perennial/intermittent streams where the daily discharge is always above zero for some years but equal to zero on some days for some other years.

Table 4 Hydro-Meteorological Station Identification

Station	Latitude (Degree & minutes)	Longitude	Station Description
Hydrologic Stations			
BC0	45 11.43	78 56.18	Blue Chalk Outflow
BC1	45 12.07	78 55.49	Blue Chalk Inflow 1
CB0	45 12.38	78 59.05	Chub Outflow
CB1	45 12.42	78 59.35	Chub Inflow 1
CB2	45 12.56	78 59.00	Chub Inflow 2
CN0	45 05.12	79 01.59	Crosson Outflow
CN1	45 04.58	79 02.29	Crosson Inflow 1
DE0	45 08.34	79 05.41	Dickie Outflow
DE5	45 08.41	79 05.22	Dickie Inflow 5
DE6	45 08.46	79 05.13	Dickie Inflow 6
DE8	45 09.09	79 05.26	Dickie Inflow 8
DE10	45 09.18	79 04.51	Dickie Inflow 10
DE11	45 08.51	79 04.45	Dickie Inflow 11
HP0	45 22.50	79 08.05	Harp Outflow
HP3	45 22.28	79 08.26	Harp Inflow 3
HP3A	45 22.29	79 08.33	Harp Inflow 3A
HP4	45 22.49	79 08.28	Harp Inflow 4
HP4_21	45 22.44	79 08.35	Harp Inflow 4 - sub-catchment 21
HP5	45 22.60	79 07.55	Harp Inflow 5
HP6	45 22.40	79 07.37	Harp Inflow 6
HP6A	45 22.46	79 07.42	Harp Inflow 6A
HY0	45 07.42	79 05.54	Heney Outflow
PC0	45 10.32	78 48.51	Plastic Outflow
PC1	45 10.41	78 49.37	Plastic Inflow 1
PC1_08	45 10.54	78 49.45	Plastic Inflow 1 - sub-catchment 08
PT1	45 13.53	78 56.13	Paint Inflow 1
RC0	45 11.11	78 56.46	Red Chalk Outflow
RC1	45 11.37	78 56.25	Red Chalk Inflow 1
RC2	45 11.26	78 56.25	Red Chalk Inflow 2
RC3	45 11.28	78 57.20	Red Chalk Inflow 3
RC4	45 11.31	78 57.18	Red Chalk Inflow 4
TWN	45 01.49	78 41.14	Twelve Mile North Inflow 1
TWS	45 01.42	78 41.09	Twelve Mile South Inflow 1
Meteorological Stations			
DOR2	45 13.00	78 56.00	Dorset Meteorologic Station (AES)
DW1	45 23.00	78 54.00	Dwight Met. Station (AES)
HAL	45 01.0	78 33.00	Haliburton Airport Met Station (AES)
HPP2	45 23.00	79 07.00	Harp Lake Met Station (DESC)
HUN	45 20.00	79 13.00	Huntsville WPTC Met Station (AES)
HYP2	45 08.00	79 06.00	Heney Lake Met Station (DESC)
MUS	44 58.00	79 18.00	Muskoka Airport Met Station (AES)
PCP2	45 11.00	78 50.00	Plastic Lake Met Station (DESC)
PT1P	45 13.00	78 56.00	Paint Lake Met Station (DESC)

AES: Atmospheric Environment Service

DESC: Dorset Environmental Science Centre (former Dorset Research Centre), Ministry of Enviornment

Table 5 Summary of meteorological and hydrological data for the Muskoka-Haliburton area

Meteorological Parameter	**Summary Value**	**Period Record**	**Stations Included in Summary**
Mean Annual Precip.	1010 mm	June 78 - May 07	PT1P, HYP2, HPP2, PCP2
Mean Annual Snowfall	2982 mm	Jan 71 – Dec 00	DOR2, HUN, MUS, DWI, HAL
Maximum Snow Depth	1096 mm	Jan 71 – Dec 00	DOR2, HUN, MUS, DWI, HAL
Mean Temperature	5.09 °C	Jan 78 – Dec 07	PT1P, HYP2, HPP2, PCP2
Mean Annual Global Radiation	4024 Kj/m^2	Jan 1978 – Dec 2007	PT1P, HYP2
Mean Annual Lake Evaporation	569 mm	Jun 78 – May 07	BC, CB, CN, DE, HP, HY, PC, RC
Mean Ice-On Date	Dec. 5	Jan 75 – Dec 06	BC, CB, CN, DE, HY, PC, RC
Mean Ice-Off Date	April 21	Jan 75 – Dec 06	BC, CB, CN, DE, HY, PC, RC
Mean Frost-free days	121.3	1984 - 1991 1978 - 1991	HPP2, HYP2, PCP2 PT1P
Mean Annual Runoff	521 mm	Jun 78 – May 07	28 study streams at 8 lake catchments

*See Table 4 for station abbreviation descriptions.

Table 6 Minimum, maximum and mean values of daily discharge (L/s) for 28 gauged watersheds, 1978-2007

Year	BC0			BC1			CB0		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1978-79	0.00	271.00	30.50	0.00	46.20	2.98	0.00	431.00	51.91
1979-80	0.00	233.00	32.52	0.00	42.60	3.40	0.22	540.00	57.05
1980-81	4.27	130.00	30.77	0.01	54.00	2.87	7.18	318.00	56.18
1981-82	0.00	182.00	23.21	0.00	71.20	2.32	0.12	441.00	39.96
1982-83	0.00	194.00	34.60	0.00	45.30	3.98	0.32	338.00	62.21
1983-84	0.00	274.00	21.42	0.00	38.20	2.83	0.00	249.00	44.92
1984-85	0.00	197.00	31.51	0.00	80.30	3.14	0.02	611.00	58.34
1985-85	0.62	146.00	24.23	0.00	58.50	2.77	1.16	431.00	44.28
1986-87	1.28	103.00	22.41	0.00	37.50	2.05	2.03	235.00	37.37
1987-88	0.00	193.00	20.69	0.00	73.10	2.11	0.00	411.00	41.48
1988-89	0.00	112.00	21.34	0.00	61.40	2.23	0.00	247.00	40.21
1989-90	0.00	106.00	22.10	0.00	78.30	3.07	0.00	270.00	39.43
1990-91	0.00	184.00	26.03	0.00	75.54	3.91	0.00	352.00	46.64
1991-92	0.00	129.00	19.83	0.00	43.48	2.45	0.00	407.00	38.50
1992-93	1.62	174.00	30.10	0.00	84.79	3.49	0.22	277.00	52.78
1993-94	0.00	71.10	22.56	0.00	30.79	2.70	0.00	225.00	43.99
1994-95	0.05	115.00	25.21	0.41	26.56	2.55	1.89	198.00	51.46
1995-96	0.00	177.00	29.61	0.25	38.33	2.97	0.52	355.00	57.70
1996-97	0.24	97.20	23.14	0.07	32.62	2.82	0.22	474.93	68.23
1997-98	0.00	217.00	17.62	0.00	79.84	1.98	0.00	559.00	27.74
1998-99	0.00	53.20	8.52	0.00	23.18	1.03	0.00	424.00	25.84
1999-00	0.00	113.00	22.99	0.04	13.98	1.96	0.00	198.00	44.93
2000-01	0.03	235.00	21.99	0.18	48.06	2.70	1.00	378.94	37.03
2001-02									
2002-03									
2003-04									
2004-05									
2005-06									
2006-07									

Table 6 (continued …)

Year	CB1			CB2			CN0		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1978-79	0.00	208.00	9.10	0.00	260.00	20.23			
1979-80	0.00	102.00	8.23	0.00	384.00	24.14			
1980-81	0.11	119.00	9.24	0.87	272.00	25.06	32.10	1050.00	125.23
1981-82	0.00	177.00	7.78	0.00	348.00	18.22	12.10	1050.00	89.61
1982-83	0.01	127.00	10.34	0.00	352.00	25.27	11.10	782.00	136.28
1983-84	0.00	85.60	7.42	0.00	151.00	18.23	2.77	592.00	91.87
1984-85	0.00	166.00	9.08	0.00	376.00	24.68	4.96	1240.00	133.70
1985-85	0.03	129.00	6.88	0.01	247.00	18.79	8.86	1060.00	96.44
1986-87	0.08	94.60	5.38	0.14	204.00	15.21	19.90	725.00	86.93
1987-88	0.00	143.00	6.53	0.00	328.00	19.85	2.18	1240.00	81.15
1988-89	0.00	128.00	6.30	0.00	245.00	17.08	3.48	477.00	91.19
1989-90	0.00	93.60	6.60	0.00	189.63	16.61	1.93	528.00	91.93
1990-91	0.00	150.00	8.52	0.00	291.61	18.90	2.40	1670.00	106.40
1991-92	0.00	138.00	6.49	0.00	550.60	17.02	1.92	901.00	78.28
1992-93	0.22	129.00	9.95	0.00	407.56	25.63	10.20	815.00	120.56
1993-94	0.04	70.90	7.62	0.00	188.00	17.75			
1994-95	0.23	104.00	9.50	0.00	155.00	21.68			
1995-96	0.06	161.00	10.05	0.00	324.00	25.92			
1996-97	0.00	118.00	10.68	0.00	231.00	28.75			
1997-98	0.00	58.30	4.05	0.00	392.00	15.40			
1998-99	0.00	59.80	3.01	0.00	119.00	15.11			
1999-00	0.00	72.20	7.61	5.98	106.00	22.29			
2000-01	0.00	159.00	5.77	0.00	333.00	14.01			
2001-02									
2002-03									
2003-04									
2004-05									
2005-06									
2006-07									

Table 6 (continued …)

Year	CN1			DE0			DE5		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1978-79				0.00	541.00	85.15	0.00	78.50	6.02
1979-80				0.00	756.00	91.99	0.00	86.30	7.14
1980-81	2.47	1250.00	93.81	16.50	970.00	112.14	0.11	84.40	7.39
1981-82	0.59	1160.00	67.53	0.00	952.00	77.69	0.00	70.40	4.33
1982-83	0.95	826.00	103.47	0.03	562.00	109.47	0.03	49.80	6.80
1983-84	0.26	549.00	81.03	0.00	451.00	79.01	0.00	51.00	5.18
1984-85	1.09	1110.00	101.97	0.00	972.00	102.43	0.00	89.80	6.23
1985-85	1.06	919.00	80.08	0.74	676.00	79.02	0.01	99.60	5.12
1986-87	0.00	768.38	64.50	0.87	416.00	59.00	0.01	61.70	3.81
1987-88	0.00	1200.00	68.36	0.00	893.89	63.83	0.00	76.70	3.81
1988-89	0.00	460.00	73.62	0.00	354.00	61.23	0.00	43.50	4.21
1989-90	0.00	767.00	75.84	0.00	424.62	58.06	0.00	67.20	4.77
1990-91	0.00	912.24	78.04	0.00	726.00	79.05	0.00	125.21	5.85
1991-92	0.00	851.00	60.80	0.00	559.00	68.98	0.00	72.90	4.44
1992-93	0.90	1090.00	89.04	1.26	639.24	96.89	0.01	90.30	5.33
1993-94				1.00	403.46	79.77	0.32	39.90	4.53
1994-95				9.41	267.00	91.05	0.77	50.10	4.81
1995-96				0.15	587.00	91.97	0.48	72.30	5.61
1996-97				0.55	461.00	101.41	0.14	67.70	5.86
1997-98				0.00	829.00	63.04	0.00	165.67	4.12
1998-99				0.00	322.00	26.53	0.00	37.00	1.64
1999-00				0.59	577.00	81.44	0.09	29.00	4.06
2000-01				0.00	602.60	77.24	0.25	66.49	3.73
2001-02				0.00	652.00	98.81	0.00	37.45	4.27
2002-03				0.00	415.70	59.75	0.00	58.00	3.49
2003-04				8.00	500.00	95.61	0.20	84.94	5.70
2004-05				0.48	438.39	77.47	0.54	64.73	5.48
2005-06				0.00	499.07	87.55	0.00	66.10	5.84
2006-07				0.00	600.00	84.00	0.02	81.58	6.42

Table 6 (continued …)

Year	DE6			DE8			DE10		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1978-79	0.00	62.00	4.78	0.00	47.70	6.90	0.00	172.00	14.48
1979-80	0.00	94.70	4.57	0.00	174.00	12.66	0.00	289.00	15.65
1980-81	0.50	62.20	5.25	0.03	209.00	16.12	1.11	201.00	16.83
1981-82	0.00	56.90	3.65	0.00	274.00	12.63	0.00	235.00	12.96
1982-83	0.02	48.70	5.15	0.00	139.00	16.55	0.00	220.00	18.16
1983-84	0.00	34.00	3.96	0.00	88.50	11.85	0.00	138.00	12.49
1984-85	0.00	73.20	4.66	0.00	191.00	13.49	0.00	227.00	14.92
1985-85	0.00	35.60	3.33	0.02	164.00	11.19	0.00	280.00	11.96
1986-87	0.04	54.60	2.93	0.24	111.00	8.39	0.18	164.00	10.27
1987-88	0.00	68.70	3.26	0.00	204.00	9.78	0.00	281.00	11.45
1988-89	0.00	29.10	3.24	0.00	78.40	9.62	0.00	82.30	10.90
1989-90	0.00	27.00	3.23	0.00	111.00	9.87	0.00	128.00	10.82
1990-91	0.00	96.30	4.72	0.00	185.00	11.64	0.00	251.00	14.59
1991-92	0.00	62.90	3.73	0.00	156.00	9.52	0.00	216.00	12.05
1992-93	0.01	74.00	4.21	0.00	172.00	13.46	0.00	257.00	14.79
1993-94	0.00	40.50	3.55	0.02	111.00	12.75	0.00	123.00	12.56
1994-95	0.00	29.50	3.67	0.93	86.00	12.89	0.47	116.00	13.98
1995-96	0.01	58.50	3.98	0.01	155.00	13.84	0.00	174.00	14.10
1996-97	0.01	36.40	4.44	0.00	105.00	14.73	0.00	178.00	15.21
1997-98	0.00	87.20	2.46	0.00	241.00	8.46	0.00	334.00	9.54
1998-99	0.00	22.10	1.18	0.00	72.10	3.94	0.00	99.00	4.68
1999-00	0.00	27.50	3.35	0.00	86.01	11.31	0.00	80.60	12.21
2000-01	0.13	75.40	3.37	0.14	203.00	9.60	0.32	295.00	12.19
2001-02	0.00	40.20	3.65	0.00	150.32	13.86	0.00	151.00	14.63
2002-03	0.00	45.78	2.66	0.00	118.46	7.88	0.00	303.26	9.41
2003-04	0.12	61.02	4.26	0.00	148.61	12.31	0.00	123.37	14.39
2004-05	0.16	41.91	3.59	0.00	102.24	9.45	0.00	134.15	10.27
2005-06	0.00	69.64	4.57	0.00	541.15	13.38	0.00	382.03	13.70
2006-07	0.12	56.73	3.94	0.00	168.93	12.04	0.00	213.25	11.02

Table 6 (continued …)

Year	DE11			HP0			HP3		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1978-79	0.00	184.00	17.37	0.00	835.00	112.60	0.00	83.90	4.58
1979-80	0.00	375.00	17.32	0.00	1340.0 0	107.52	0.00	74.70	4.55
1980-81	0.97	249.00	15.55	3.73	561.00	104.70	0.27	70.60	6.02
1981-82	0.00	196.00	12.36	0.00	958.00	94.86	0.00	114.0 0	5.60
1982-83	0.00	194.00	16.90	0.00	720.00	111.83	0.00	70.90	6.00
1983-84	0.00	105.00	11.44	0.00	497.00	81.25	0.00	43.40	4.62
1984-85	0.00	253.00	15.05	0.01	1170.0 0	117.57	0.03	90.60	5.85
1985-85	0.00	180.00	11.86	0.07	1020.0 0	114.98	0.11	93.53	5.91
1986-87	0.00	156.00	9.17	0.01	714.00	76.35	0.12	57.30	3.67
1987-88	0.00	229.00	10.99	0.00	904.00	76.82	0.00	80.90	4.16
1988-89	0.00	88.20	10.53	0.00	565.00	79.19	0.00	49.90	4.23
1989-90	0.00	94.20	11.27	0.00	612.00	72.86	0.00	60.50	3.67
1990-91	0.00	318.00	14.26	0.00	784.00	94.45	0.00	78.60	4.69
1991-92	0.00	180.00	10.35	0.00	856.00	74.06	0.00	74.20	3.70
1992-93	0.00	262.18	14.64	0.00	768.00	102.48	0.00	149.9 0	5.30
1993-94	0.00	171.00	11.32	0.00	515.00	82.28	0.00	65.50	4.45
1994-95	0.10	103.20	12.50	1.70	428.00	102.08	0.19	42.80	4.95
1995-96	0.10	169.44	13.83	0.01	787.00	130.83	0.07	62.70	6.45
1996-97	0.10	173.33	14.90	0.13	794.40	122.60	0.03	92.70	6.09
1997-98	0.10	325.15	9.39	0.00	1270.0 0	56.53	0.00	105.0 0	2.81
1998-99	0.10	96.45	4.66	0.00	495.00	46.58	0.00	43.30	2.48
1999-00	0.10	78.54	11.99	0.00	351.00	88.82	0.00	54.60	4.56
2000-01	0.41	287.20	11.96	0.05	753.00	69.89	0.01	79.30	3.48
2001-02	0.10	147.06	14.34	0.00	800.00	104.38	0.00	63.30	5.18
2002-03	0.10	294.67	9.13	0.00	350.00	47.04	0.00	46.52	3.13
2003-04	0.06	119.91	14.04	2.88	718.65	99.17	0.00	87.94	6.90
2004-05	0.06	130.38	10.04	0.00	563.33	66.08	0.00	74.14	3.77
2005-06	0.06	371.20	13.37	0.00	609.61	68.17	0.00	55.70	3.06
2006-07	0.06	207.22	10.76	0.48	328.40	86.10	0.00	29.77	3.13

Table 6 (continued …)

Year	HP3a			HP4			HP5		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1978-79	0.01	83.60	4.47	1.51	365.00	28.89	0.51	484.00	35.93
1979-80	0.00	54.20	3.75	0.00	459.00	24.39	0.00	823.00	44.79
1980-81	0.28	91.20	4.48	1.70	192.00	24.90	1.11	414.00	42.62
1981-82	0.09	89.20	4.02	1.13	304.40	21.08	0.29	765.00	40.52
1982-83	0.07	52.70	4.27	0.75	153.00	22.62	0.08	493.00	44.61
1983-84	0.00	59.90	3.32	0.76	145.00	17.80	0.00	288.00	31.76
1984-85	0.04	73.00	4.28	1.14	341.00	24.45	0.39	840.72	46.64
1985-85	0.09	134.00	4.50	1.36	268.00	24.75	1.27	654.00	43.30
1986-87	0.09	51.00	2.59	1.09	219.00	15.55	1.02	430.00	27.75
1987-88	0.02	59.10	3.06	0.27	247.00	16.86	0.00	651.00	31.60
1988-89	0.01	95.00	3.28	0.23	235.00	17.26	0.03	922.00	32.16
1989-90	0.01	79.60	2.76	0.18	173.00	15.85	0.04	427.00	27.73
1990-91	0.00	138.00	3.70	0.34	285.00	20.03	0.09	675.90	36.54
1991-92	0.01	46.30	2.84	0.42	284.00	16.56	0.01	649.00	28.60
1992-93	0.03	115.11	3.86	1.09	440.00	22.83	0.33	625.00	40.02
1993-94	0.00	30.02	3.21	1.33	194.00	19.85	0.22	581.09	32.40
1994-95	0.10	65.30	3.75	2.09	189.00	22.18	1.41	383.00	37.55
1995-96	0.06	140.00	5.06	1.83	247.00	29.35	0.03	559.00	51.20
1996-97	0.04	67.21	4.35	0.05	256.00	26.05	0.00	726.00	50.19
1997-98	0.02	95.40	2.23	0.55	373.00	11.52	0.00	746.00	20.54
1998-99	0.00	35.62	1.83	0.28	141.00	9.59	0.00	288.00	17.74
1999-00	0.01	42.30	3.33	0.60	206.00	19.01	0.00	252.00	26.07
2000-01	0.07	64.70	3.39	1.07	92.50	13.03	0.03	493.00	21.66
2001-02	0.02	94.40	4.43	0.39	215.00	25.41	0.00	489.00	41.61
2002-03	0.00	56.24	3.13	0.00	100.00	10.46	0.00	200.00	17.93
2003-04	0.00	70.42	2.81	0.06	263.07	17.30	0.00	489.38	29.87
2004-05	0.13	86.13	2.53	1.59	166.56	14.42	0.28	308.86	24.29
2005-06	0.01	55.70	2.96	0.00	259.55	18.40	0.00	413.89	26.88
2006-07	0.15	35.01	3.69	0.00	200.33	16.01	0.00	372.02	27.71

Table 6 (continued …)

Year	HP6			HP6a			HY0		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1978-79	0.00	34.00	2.60	0.00	45.00	2.63			
1979-80	0.00	35.70	2.20	0.00	41.60	2.74			
1980-81	0.01	20.10	2.22	0.01	71.30	3.14	1.21	135.00	20.84
1981-82	0.00	44.10	2.21	0.00	61.10	2.48	0.00	122.00	13.25
1982-83	0.00	23.90	2.25	0.00	45.00	3.08	0.00	80.10	19.48
1983-84	0.00	15.60	1.70	0.00	26.20	2.12	0.00	55.10	14.06
1984-85	0.00	40.00	2.22	0.00	41.40	2.91	0.00	152.00	19.94
1985-85	0.00	36.00	2.38	0.00	52.50	2.79	0.02	71.70	15.33
1986-87	0.00	24.10	1.50	0.00	39.40	1.79	0.10	99.70	11.77
1987-88	0.00	30.40	1.49	0.00	32.35	1.73	0.00	100.00	12.73
1988-89	0.00	29.00	1.64	0.00	42.40	2.06	0.00	66.00	14.00
1989-90	0.00	28.60	1.39	0.00	27.70	1.67	0.00	59.60	10.54
1990-91	0.00	35.50	1.74	0.00	59.00	2.22	0.00	99.80	14.88
1991-92	0.00	33.50	1.42	0.00	36.70	1.85	0.00	74.10	11.34
1992-93	0.00	34.23	1.99	0.00	71.20	2.62	0.00	86.80	19.15
1993-94	0.00	21.20	1.73	0.00	37.70	2.16			
1994-95	0.08	16.60	1.94	0.04	32.10	2.45			
1995-96	0.00	23.94	2.44	0.00	44.70	3.27			
1996-97	0.00	31.80	2.57	0.00	55.00	3.16			
1997-98	0.00	38.40	1.12	0.00	53.70	1.38			
1998-99	0.00	14.30	1.09	0.00	22.90	1.17			
1999-00	0.00	18.80	1.85	0.00	27.60	2.36			
2000-01	0.02	23.43	1.34	0.03	37.00	1.75			
2001-02	0.00	29.10	1.99	0.00	43.40	2.55			
2002-03	0.00	35.00	1.35	0.00	51.59	1.72			
2003-04	0.00	31.35	1.71	0.00	31.59	2.55			
2004-05	0.00	32.23	1.19	0.00	33.21	1.29			
2005-06	0.00	26.12	1.54	0.00	23.35	1.74			
2006-07	0.00	10.74	0.64	0.00	16.69	1.45			

Table 6 (continued …)

Year	PC0			PC1			RC0		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1978-79	0.00	119.82	19.45	0.00	52.32	4.01	0.97	1020.00	128.27
1979-80	1.04	264.00	22.78	0.00	93.30	4.70	0.00	956.00	125.36
1980-81	0.87	195.00	19.91	0.08	79.00	4.71	28.00	699.00	118.03
1981-82	0.54	210.00	18.00	0.00	70.10	3.54	0.27	935.00	94.71
1982-83	1.99	411.00	28.83	0.00	71.30	5.97	0.45	710.00	138.19
1983-84	1.62	129.00	19.20	0.00	38.00	4.12	0.00	471.00	93.99
1984-85	0.68	302.00	24.18	0.00	82.80	4.69	0.12	976.00	115.27
1985-85	0.99	169.00	19.49	0.01	56.40	3.72	14.40	731.00	93.76
1986-87	3.49	117.00	19.99	0.03	52.30	3.41	31.20	478.00	84.18
1987-88	0.00	164.00	16.04	0.00	69.10	3.31	0.00	865.00	80.79
1988-89	0.61	102.00	17.62	0.00	33.70	3.67	0.00	483.00	86.82
1989-90	0.00	76.60	18.37	0.00	62.94	3.84	0.00	506.00	85.92
1990-91	0.00	586.00	21.07	0.00	104.00	4.28	0.00	851.00	102.64
1991-92	2.05	132.00	17.36	0.00	71.80	3.24	0.00	694.00	83.68
1992-93	0.33	318.00	22.96	0.00	61.90	4.46	16.90	660.00	117.40
1993-94	0.61	227.00	15.02	0.00	42.90	3.30	3.73	381.00	92.49
1994-95	0.82	133.93	19.02	0.07	49.70	3.69	10.20	345.26	102.80
1995-96	0.52	204.00	24.35	0.00	96.76	5.04	1.00	550.00	115.58
1996-97	5.25	176.00	29.76	0.11	46.80	5.56	11.79	631.80	124.92
1997-98	0.33	337.00	14.18	0.00	95.00	2.73	14.50	1040.00	79.09
1998-99	0.00	56.00	7.77	0.00	36.50	1.80	0.00	315.00	35.71
1999-00	1.10	91.70	21.48	0.00	43.40	4.67	3.13	258.00	93.64
2000-01	0.57	127.00	17.61	0.03	118.00	3.13	11.10	732.00	83.87
2001-02	0.22	134.00	20.15	0.00	47.50	4.75			
2002-03	0.95	110.00	13.59	0.00	69.70	3.49			
2003-04	1.86	177.41	25.89	0.00	62.90	4.20			
2004-05	1.97	121.89	15.41	0.00	36.68	3.45			
2005-06	0.00	331.89	18.52	0.00	79.78	4.65			
2006-07	0.00	132.18	15.06	0.00	38.33	3.66			

Table 6 (continued …)

Year	RC1			RC2			RC3		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1978-79	0.47	378.00	27.68	0.00	48.20	5.55	1.69	201.00	17.49
1979-80	0.38	402.00	27.95	0.00	73.40	4.72	0.44	185.00	16.80
1980-81	1.03	357.00	24.65	0.00	63.40	5.14	1.33	156.00	15.22
1981-82	0.72	338.50	17.55	0.00	70.80	3.94	1.05	160.00	11.02
1982-83	0.00	428.00	30.49	0.00	73.10	6.27	1.01	167.00	15.65
1983-84	0.00	253.00	19.62	0.00	40.30	4.47	0.25	106.00	10.99
1984-85	0.12	398.00	25.52	0.00	69.90	5.10	0.87	259.00	15.51
1985-85	0.07	408.00	20.40	0.00	49.60	4.16	2.53	249.00	12.84
1986-87	0.79	261.00	18.15	0.00	49.70	3.61	3.32	92.50	11.89
1987-88	0.00	486.00	18.54	0.00	68.00	3.82	0.26	219.00	11.39
1988-89	0.00	376.00	20.07	0.00	39.30	4.12	0.13	95.00	12.34
1989-90	0.00	341.00	18.90	0.00	64.10	3.96	0.15	129.00	11.31
1990-91	0.00	432.00	22.52	0.00	80.20	4.64	0.13	184.00	13.55
1991-92	0.00	366.00	18.49	0.00	64.45	3.61	0.14	223.00	10.73
1992-93	0.14	587.60	29.22	0.00	73.50	5.52	1.89	241.00	15.89
1993-94	0.00	152.00	18.54	0.00	45.60	4.06	1.18	109.00	11.82
1994-95	0.00	175.96	21.54	0.02	40.50	4.61	1.90	185.32	13.26
1995-96	0.00	418.00	27.14	0.00	65.30	5.20	1.58	154.65	14.97
1996-97	0.09	370.02	29.43	0.00	48.20	5.93	2.35	229.20	18.63
1997-98	0.00	574.00	15.50	0.00	79.70	3.02	1.06	265.42	11.84
1998-99	0.00	208.00	8.02	0.00	27.30	1.75	0.75	34.41	4.51
1999-00	0.00	150.00	21.55	0.00	25.40	4.16	1.07	83.40	12.28
2000-01	0.00	361.00	15.87	0.00	48.75	2.87	1.11	211.00	9.60
2001-02									
2002-03									
2003-04									
2004-05									
2005-06									
2006-07									

Table 6 (continued …)

Year	RC4		
	Min	Max	Mean
1978-79	0.12	97.40	8.90
1979-80	0.02	92.50	8.37
1980-81	0.67	60.80	7.80
1981-82	0.26	96.40	6.69
1982-83	0.61	98.00	10.12
1983-84	0.19	65.90	7.33
1984-85	0.58	149.00	9.50
1985-85	0.70	120.00	7.63
1986-87	0.74	73.00	6.47
1987-88	0.22	136.00	6.95
1988-89	0.00	172.00	6.93
1989-90	0.15	104.00	7.09
1990-91	0.12	153.00	8.31
1991-92	0.25	88.60	6.55
1992-93	0.61	207.16	10.38
1993-94	0.56	68.06	7.57
1994-95	0.99	55.10	8.35
1995-96	0.78	114.00	10.88
1996-97	2.09	159.00	11.95
1997-98	1.22	147.00	6.64
1998-99	0.54	30.30	3.89
1999-00	0.79	77.10	9.45
2000-01	1.96	205.00	8.34
2001-02			
2002-03			
2003-04			
2004-05			
2005-06			
2006-07			

Table 7 Total annual runoff (10^3 m^3/yr) for 28 gauged watersheds, 1978-2007

Watershed	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	1985-85	1986-87	1987-88
BC0	962	1025	970	732	1091	676	994	764	707	652
BC1	94	107	91	73	125	89	99	87	65	67
CB0	1637	1799	1772	1260	1962	1416	1840	1396	1179	1308
CB1	287	260	291	245	326	234	286	217	170	206
CB2	638	761	790	575	797	575	778	593	480	626
CN0			3949	2826	4298	2897	4216	3041	2741	2559
CN1			2958	2130	3263	2555	3216	2525	2034	2156
DE0	2685	2901	3536	2450	3452	2492	3230	2492	1861	2013
DE5	190	225	233	136	214	163	197	161	120	120
DE6	151	144	166	115	162	125	147	105	92	103
DE8	218	399	508	398	522	374	425	353	264	308
DE10	457	494	531	409	573	394	470	377	324	361
DE11	548	546	491	390	533	361	475	374	289	347
HP0	3551	3391	3302	2992	3527	2562	3708	3626	2408	2422
HP3	144	143	190	177	189	146	184	186	116	131
HP3A	141	118	141	127	135	105	135	142	82	97
HP4	911	769	785	665	713	561	771	780	490	532
HP5	1133	1412	1344	1278	1407	1002	1471	1366	875	997
HP6	82	69	70	70	71	54	70	75	47	47
HP6A	83	86	99	78	97	67	92	88	56	55
HY0			657	418	614	443	629	484	371	401
PC0	613	718	628	568	909	605	762	615	630	506
PC1	127	148	149	112	188	130	148	117	108	104
RC0	4045	3953	3722	2987	4358	2964	3635	2957	2655	2548
RC1	873	881	777	553	961	619	805	643	572	585
RC2	175	149	162	124	198	141	161	131	114	120
RC3	552	530	480	348	493	347	489	405	375	359
RC4	281	264	246	211	319	231	300	240	204	219

Table 7 (continued…)

Watershed	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
BC0	673	697	821	625	949	711	795	934	730	556
BC1	70	97	123	77	110	85	80	94	89	63
CB0	1268	1243	1471	1214	1665	1387	1623	1820	2152	875
CB1	199	208	269	205	314	240	299	317	337	128
CB2	539	524	596	537	808	560	684	818	907	486
CN0	2876	2899	3355	2469	3802					
CN1	2322	2392	2461	1917	2808					
DE0	1931	1831	2493	2175	3055	2516	2871	2900	3198	1988
DE5	133	150	185	140	168	143	152	177	185	130
DE6	102	102	149	118	133	112	116	125	140	78
DE8	303	311	367	300	424	402	406	436	465	267
DE10	344	341	460	380	466	396	441	445	480	301
DE11	332	355	450	326	462	357	394	436	470	296
HP0	2497	2298	2979	2335	3232	2595	3219	4126	3866	1783
HP3	133	116	148	117	167	140	156	203	192	89
HP3A	103	87	117	90	122	101	118	159	137	70
HP4	544	500	632	522	720	626	700	926	821	363
HP5	1014	875	1152	902	1262	1022	1184	1615	1583	648
HP6	52	44	55	45	63	54	61	77	81	35
HP6A	65	53	70	58	83	68	77	103	100	43
HY0	441	333	469	357	604					
PC0	556	579	665	548	724	474	600	768	938	447
PC1	116	121	135	102	141	104	116	159	175	86
RC0	2738	2710	3237	2639	3702	2917	3242	3645	3940	2494
RC1	633	596	710	583	922	585	679	856	928	489
RC2	130	125	146	114	174	128	145	164	187	95
RC3	389	357	427	339	501	373	418	472	588	373
RC4	219	224	262	207	327	239	263	343	377	210

Table 7 (continued…)

Watershed	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
BC0	269	725	693						
BC1	32	62	85						
CB0	815	1417	1168						
CB1	95	240	182						
CB2	477	703	442						
CN0									
CN1									
DE0	837	2568	2436	3116	1884	3015	2443	2761	2649
DE5	52	128	118	135	110	180	173	184	203
DE6	37	106	106	115	84	134	113	144	124
DE8	124	357	303	437	249	388	298	422	380
DE10	148	385	384	461	297	454	324	432	348
DE11	147	378	377	452	288	443	316	422	339
HP0	1469	2801	2204	3292	1483	3127	2084	2150	2715
HP3	78	144	110	163	99	218	119	97	99
HP3A	58	105	107	140	99	89	80	93	116
HP4	302	599	411	801	330	546	455	580	505
HP5	559	822	683	1312	565	942	766	848	874
HP6	34	58	42	63	43	54	38	48	20
HP6A	37	75	55	80	54	80	41	55	46
HY0									
PC0	245	678	555	635	429	816	486	584	475
PC1	57	147	99	150	110	132	109	147	116
RC0	1126	2953	2645						
RC1	253	679	501						
RC2	55	131	91						
RC3	142	387	303						
RC4	123	298	263						

Table 8 Annual areal runoff (mm/yr) for 28 gauged watersheds, 1978-07

Watershed	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	1985-85	1986-87	1987-88
BC0	608	648	613	463	689	427	628	483	446	412
BC1	460	525	443	359	614	437	484	427	316	326
CB0	534	588	579	412	641	463	601	456	385	427
CB1	481	435	488	411	546	392	480	363	284	345
CB2	506	604	627	456	633	456	618	470	381	497
CN0			683	489	743	501	729	526	474	442
CN1			648	467	715	560	705	553	446	472
DE0	537	580	707	490	690	498	646	498	372	403
DE5	633	751	778	455	715	545	656	538	401	400
DE6	692	661	760	528	745	572	674	482	423	472
DE8	325	596	759	595	779	558	635	527	395	461
DE10	579	626	673	518	726	499	596	478	410	458
DE11	718	716	643	511	699	473	622	490	379	454
HP0	655	626	609	552	651	473	684	669	444	447
HP3	555	551	730	679	727	561	709	716	445	505
HP3A	718	603	719	645	685	533	686	723	416	491
HP4	765	646	659	558	599	471	647	655	412	447
HP5	595	741	705	671	738	526	772	717	459	523
HP6	823	697	703	700	713	537	701	753	475	473
HP6A	543	565	648	511	636	438	600	575	369	358
HY0			707	449	660	477	676	520	399	431
PC0	480	563	492	445	712	474	597	482	494	396
PC1	542	635	636	478	806	557	633	502	461	447
RC0	686	671	631	507	739	503	617	502	450	432
RC1	654	660	582	414	720	463	602	481	428	438
RC2	650	552	601	460	733	523	597	487	423	447
RC3	783	752	681	493	700	492	694	574	532	510
RC4	617	581	541	464	702	509	659	529	449	482
Mean	606	623	645	506	695	497	641	542	420	443
n	25	25	28	28	28	28	28	28	28	28

Table 8 (continued…)

Watershed	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
BC0	425	440	519	395	600	450	502	590	461	351
BC1	345	474	604	379	539	417	394	459	436	306
CB0	414	406	480	396	544	453	530	594	703	286
CB1	333	349	450	343	526	403	502	531	564	214
CB2	428	416	473	426	641	444	543	649	720	386
CN0	497	501	580	427	657					
CN1	509	524	539	420	615					
DE0	386	366	499	435	611	503	574	580	640	398
DE5	443	502	616	467	561	477	506	590	616	433
DE6	469	467	682	539	609	514	531	575	643	356
DE8	453	465	548	448	634	600	607	652	694	398
DE10	436	433	583	482	591	502	559	564	608	381
DE11	436	466	589	428	605	468	517	572	616	388
HP0	461	424	550	431	596	479	594	761	713	329
HP3	513	445	569	449	642	540	600	782	738	340
HP3A	527	443	594	456	620	515	602	811	699	358
HP4	457	420	530	438	605	526	587	777	690	305
HP5	532	459	605	473	662	536	622	847	831	340
HP6	520	440	551	448	629	546	613	772	812	353
HP6A	424	345	457	382	541	445	505	676	653	284
HY0	475	357	504	384	649					
PC0	435	454	521	429	567	371	470	602	735	350
PC1	496	519	578	438	603	446	499	681	751	368
RC0	464	460	549	448	628	495	550	618	668	423
RC1	474	446	532	437	690	438	509	641	695	366
RC2	482	463	542	422	645	475	539	609	694	353
RC3	552	506	606	480	711	529	593	670	833	530
RC4	481	492	576	454	720	525	580	754	829	461
Mean	459	446	551	434	616	484	545	654	682	362
n	28	28	28	28	28	25	25	25	25	25

Table 8 (continued…)

Watershed	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
BC0	170	458	438						
BC1	158	302	416						
CB0	266	463	381						
CB1	159	402	305						
CB2	378	558	351						
CN0									
CN1									
DE0	167	514	487	623	377	603	489	552	530
DE5	172	427	392	449	367	600	577	614	676
DE6	171	485	487	528	385	616	519	661	570
DE8	185	533	452	653	371	580	445	630	567
DE10	187	488	487	585	376	575	411	548	441
DE11	193	496	495	593	378	581	415	553	445
HP0	271	517	407	607	274	577	384	397	501
HP3	301	553	423	628	379	837	457	371	380
HP3A	294	534	544	711	503	452	406	476	592
HP4	254	503	345	673	277	458	382	487	424
HP5	294	431	358	689	297	494	402	445	459
HP6	346	584	423	630	429	540	377	486	201
HP6A	242	488	361	526	355	525	266	359	300
HY0									
PC0	192	531	435	498	336	640	381	457	372
PC1	243	631	423	642	472	567	466	628	495
RC0	191	501	449						
RC1	189	509	375						
RC2	205	487	336						
RC3	202	549	429						
RC4	270	655	578						
Mean	228	504	423	602	372	576	425	511	463
n	25	25	25	15	15	15	15	15	15

Table 9 Minimum and maximum annual runoff (mm/yr) and their occurrence year, for the 28 gauged watersheds, 1978-2007

Watershed	Minimum	Year	Maximum	Year
BC0	170	1998-99	689	1982-83
BC1	158	"	614	"
CB0	266	"	703	1996-97
CB1	159	"	564	"
CB2	351	2000-01	720	"
CN0	427	1991-92	743	1982-83
CN1	420	"	715	"
DE0	167	1998-99	707	1980-81
DE5	172	"	778	"
DE6	171	"	760	"
DE8	185	"	779	1982-83
DE10	187	"	726	"
DE11	193	"	718	1978-79
HP0	271	1998-99	761	1995-96
HP3	301	"	837	2003-04
HP3A	294	"	811	1995-96
HP4	254	"	777	"
HP5	294	"	847	"
HP6	346	"	823	1978-79
HP6A	242	"	676	1994-95
HY0	357	1989-90	707	1980-81
PC0	192	1998-99	735	1996-97
PC1	243	"	806	1982-83
RC0	191	"	739	"
RC1	189	"	720	"
RC2	205	"	733	"
RC3	202	"	833	1996-97
RC4	270	"	829	"

Table 10 Annual yield (ratio of runoff to precipitation) for 28 gauged watersheds, 1978-2007

Watershed	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	1985-85	1986-87	1987-88
BC0	0.476	0.540	0.512	0.468	0.568	0.416	0.567	0.452	0.436	0.423
BC1	0.360	0.437	0.370	0.363	0.506	0.426	0.437	0.400	0.309	0.335
CB0	0.419	0.489	0.483	0.416	0.528	0.451	0.543	0.427	0.376	0.439
CB1	0.377	0.362	0.407	0.416	0.450	0.382	0.433	0.340	0.278	0.354
CB2	0.397	0.503	0.523	0.461	0.521	0.445	0.558	0.440	0.372	0.510
CN0			0.570	0.494	0.612	0.505	0.646	0.520	0.490	0.463
CN1			0.541	0.472	0.589	0.565	0.625	0.547	0.461	0.494
DE0	0.421	0.483	0.590	0.496	0.569	0.502	0.572	0.493	0.385	0.421
DE5	0.496	0.626	0.649	0.461	0.589	0.549	0.581	0.532	0.414	0.419
DE6	0.542	0.551	0.634	0.534	0.614	0.577	0.598	0.477	0.438	0.493
DE8	0.255	0.497	0.633	0.602	0.642	0.563	0.563	0.521	0.408	0.482
DE10	0.454	0.521	0.561	0.524	0.598	0.503	0.528	0.473	0.424	0.479
DE11	0.563	0.596	0.537	0.517	0.576	0.477	0.551	0.485	0.392	0.475
HP0	0.514	0.521	0.508	0.558	0.536	0.477	0.616	0.563	0.469	0.466
HP3	0.435	0.459	0.609	0.687	0.599	0.565	0.639	0.603	0.469	0.527
HP3A	0.563	0.502	0.600	0.653	0.564	0.538	0.619	0.608	0.438	0.513
HP4	0.600	0.538	0.550	0.565	0.494	0.475	0.583	0.551	0.434	0.466
HP5	0.466	0.618	0.589	0.679	0.609	0.530	0.696	0.603	0.484	0.546
HP6	0.645	0.581	0.587	0.709	0.588	0.541	0.632	0.633	0.501	0.493
HP6A	0.426	0.471	0.541	0.517	0.524	0.442	0.540	0.483	0.389	0.374
HY0			0.590	0.455	0.544	0.481	0.599	0.514	0.412	0.451
PC0	0.377	0.469	0.411	0.450	0.587	0.472	0.567	0.473	0.500	0.441
PC1	0.425	0.529	0.531	0.484	0.665	0.554	0.601	0.493	0.466	0.498
RC0	0.538	0.559	0.527	0.513	0.609	0.490	0.557	0.470	0.440	0.444
RC1	0.512	0.550	0.486	0.419	0.593	0.451	0.544	0.451	0.418	0.450
RC2	0.509	0.460	0.502	0.466	0.604	0.510	0.539	0.456	0.413	0.459
RC3	0.613	0.626	0.568	0.499	0.577	0.479	0.627	0.538	0.519	0.524
RC4	0.484	0.484	0.451	0.470	0.579	0.496	0.595	0.495	0.438	0.496
Mean	0.475	0.519	0.538	0.512	0.573	0.495	0.577	0.501	0.428	0.462
n	25	25	28	28	28	28	28	28	28	28

Table 10 (continued…)

Watershed	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
BC0	0.396	0.562	0.585	0.515	0.625	0.471	0.525	0.545	0.431	0.508
BC1	0.321	0.605	0.682	0.493	0.562	0.437	0.411	0.424	0.407	0.443
CB0	0.386	0.518	0.542	0.516	0.567	0.475	0.554	0.549	0.656	0.413
CB1	0.310	0.445	0.508	0.447	0.548	0.422	0.524	0.491	0.527	0.309
CB2	0.398	0.531	0.534	0.555	0.669	0.465	0.567	0.599	0.672	0.558
CN0	0.513	0.518	0.549	0.463	0.575					
CN1	0.525	0.542	0.511	0.456	0.538					
DE0	0.398	0.379	0.472	0.472	0.534	0.510	0.576	0.523	0.576	0.475
DE5	0.456	0.519	0.583	0.507	0.491	0.484	0.508	0.532	0.555	0.517
DE6	0.484	0.483	0.646	0.585	0.533	0.521	0.533	0.518	0.579	0.425
DE8	0.467	0.481	0.519	0.486	0.554	0.609	0.609	0.587	0.625	0.476
DE10	0.449	0.447	0.552	0.523	0.517	0.509	0.561	0.508	0.548	0.455
DE11	0.449	0.482	0.558	0.464	0.529	0.475	0.519	0.515	0.555	0.463
HP0	0.479	0.505	0.548	0.491	0.598	0.525	0.571	0.609	0.601	0.442
HP3	0.533	0.531	0.567	0.512	0.644	0.593	0.577	0.626	0.623	0.458
HP3A	0.547	0.528	0.592	0.520	0.621	0.565	0.579	0.649	0.589	0.481
HP4	0.475	0.500	0.529	0.500	0.606	0.577	0.565	0.622	0.582	0.410
HP5	0.553	0.547	0.603	0.540	0.664	0.588	0.597	0.678	0.701	0.457
HP6	0.540	0.524	0.549	0.511	0.631	0.599	0.589	0.618	0.685	0.475
HP6A	0.441	0.411	0.456	0.435	0.542	0.488	0.486	0.541	0.551	0.382
HY0	0.489	0.370	0.478	0.417	0.568					
PC0	0.461	0.506	0.516	0.465	0.530	0.418	0.501	0.545	0.612	0.442
PC1	0.525	0.579	0.572	0.475	0.563	0.502	0.532	0.617	0.626	0.465
RC0	0.433	0.587	0.619	0.583	0.655	0.518	0.574	0.571	0.624	0.612
RC1	0.441	0.569	0.600	0.569	0.719	0.459	0.531	0.592	0.649	0.530
RC2	0.449	0.591	0.612	0.550	0.673	0.498	0.563	0.562	0.648	0.510
RC3	0.514	0.646	0.684	0.625	0.741	0.554	0.620	0.619	0.778	0.766
RC4	0.448	0.628	0.650	0.592	0.751	0.550	0.605	0.697	0.775	0.667
Mean	0.460	0.519	0.565	0.510	0.598	0.512	0.551	0.574	0.607	0.486
n	28	28	28	28	28	25	25	25	25	25

Table 10 (continued…)

Watershed	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
BC0	0.267	0.450	0.562						
BC1	0.250	0.297	0.534						
CB0	0.419	0.455	0.490						
CB1	0.250	0.395	0.391						
CB2	0.596	0.548	0.450						
CN0									
CN1									
DE0	0.221	0.487	0.530	0.572	0.445	0.651	0.545	0.534	0.390
DE5	0.227	0.405	0.427	0.412	0.434	0.647	0.644	0.594	0.497
DE6	0.225	0.460	0.530	0.485	0.454	0.665	0.579	0.640	0.419
DE8	0.245	0.505	0.492	0.599	0.439	0.626	0.497	0.610	0.417
DE10	0.247	0.463	0.530	0.537	0.445	0.621	0.458	0.530	0.324
DE11	0.254	0.470	0.539	0.544	0.446	0.627	0.463	0.535	0.328
HP0	0.396	0.496	0.428	0.529	0.312	0.538	0.478	0.411	0.471
HP3	0.440	0.531	0.445	0.547	0.433	0.780	0.569	0.385	0.357
HP3A	0.430	0.513	0.573	0.620	0.574	0.421	0.505	0.493	0.557
HP4	0.371	0.483	0.363	0.586	0.316	0.427	0.475	0.505	0.399
HP5	0.429	0.414	0.377	0.600	0.339	0.461	0.500	0.461	0.431
HP6	0.506	0.561	0.445	0.549	0.489	0.503	0.468	0.504	0.189
HP6A	0.353	0.468	0.380	0.458	0.405	0.490	0.330	0.372	0.282
HY0									
PC0	0.281	0.468	0.464	0.454	0.413	0.596	0.391	0.470	0.431
PC1	0.356	0.556	0.451	0.585	0.580	0.528	0.479	0.645	0.574
RC0	0.301	0.492	0.576						
RC1	0.298	0.500	0.481						
RC2	0.323	0.478	0.431						
RC3	0.318	0.540	0.551						
RC4	0.425	0.644	0.742						
Mean	0.337	0.483	0.487	0.538	0.435	0.572	0.492	0.513	0.404
n	25	25	25	15	15	15	15	15	15

Table 11 Minimum, maximum annual yield and their occurrence year, for the 28 gauged watersheds, 1978-2007

Watershed	Minimum	Year	Maximum	Year
BC0	0.267	1998-99	0.625	1992-93
BC1	0.250	"	0.682	1990-91
CB0	0.376	1986-87	0.656	1996-97
CB1	0.250	1998-99	0.548	1992-93
CB2	0.372	1986-87	0.672	1996-97
CN0	0.463	1987-88	0.646	1984-85
CN1	0.456	1991-92	0.625	"
DE0	0.221	1998-99	0.651	2003-04
DE5	0.227	"	0.649	1980-81
DE6	0.225	"	0.665	2003-04
DE8	0.245	"	0.642	1982-83
DE10	0.247	"	0.621	2003-04
DE11	0.254	"	0.627	"
HP0	0.312	2002-03	0.616	1984-85
HP3	0.357	2006-07	0.780	2003-04
HP3A	0.421	2003-04	0.653	1981-82
HP4	0.316	2002-03	0.622	1995-96
HP5	0.339	"	0.701	1996-97
HP6	0.189	2006-07	0.709	1981-82
HP6A	0.282	"	0.551	1996-97
HY0	0.370	1989-90	0.599	1984-85
PC0	0.281	1998-99	0.612	1996-97
PC1	0.356	"	0.665	1982-83
RC0	0.301	"	0.655	1992-93
RC1	0.298	"	0.719	"
RC2	0.323	"	0.673	"
RC3	0.318	"	0.778	1996-97
RC4	0.425	"	0.775	"

Table 12 Seasonal distribution of runoff from each stream watershed as a % for the 28 gauged watersheds, 1978-2007

STN	Peak Runoff (Mar-May)			Secondary Runoff (Oct-Dec)			Residual Runoff (Jun-Sep & Jan-Feb)		
	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min
BC0	64.2	47.4	30.3	41.5	21.9	0.0	49.1	30.7	17.8
BC1	82.0	59.5	41.3	43.8	24.3	6.6	36.9	16.2	5.0
CB0	85.7	55.9	35.0	39.6	22.4	0.2	33.7	21.8	12.5
CB1	74.8	57.9	34.5	38.6	23.4	6.9	33.2	18.7	6.8
CB2	75.5	56.1	33.2	37.8	23.7	5.3	38.8	20.3	6.9
CN0	60.8	47.9	32.6	38.9	22.9	14.3	39.4	29.2	21.6
CN1	60.5	50.4	34.1	39.2	28.8	20.0	36.4	20.9	11.8
DE0	69.0	50.8	24.7	44.1	24.0	0.3	43.8	25.2	14.9
DE5	78.4	58.5	40.3	39.4	22.6	6.3	38.0	18.8	4.1
DE6	79.8	58.2	35.4	40.1	23.4	4.2	40.5	18.4	5.9
DE8	74.6	54.9	27.8	38.9	23.5	4.1	68.0	21.6	6.3
DE10	78.9	58.2	38.8	38.4	22.9	4.9	38.0	18.9	7.9
DE11	79.2	58.9	40.8	37.1	22.6	5.4	38.1	18.5	5.8
HP0	71.6	51.0	33.2	39.7	24.3	5.5	36.2	24.7	11.8
HP3	79.8	54.1	16.1	66.6	25.5	5.3	41.2	20.4	7.4
HP3A	84.8	57.2	30.7	50.9	22.9	2.3	45.6	19.9	6.2
HP4	72.4	52.5	34.4	39.3	24.5	8.0	40.3	23.0	9.5
HP5	92.9	57.4	37.4	40.2	24.2	5.2	34.3	19.9	6.3
HP6	79.9	55.8	37.1	40.1	24.5	5.3	44.4	19.7	5.1
HP6A	91.5	58.2	16.7	67.6	23.6	0.0	39.5	18.1	5.1
HY0	64.6	52.6	32.3	40.3	25.6	12.3	37.5	21.8	10.9
PC0	66.2	45.4	22.3	44.9	24.9	4.3	54.3	29.6	16.3
PC1	70.6	54.6	38.2	55.6	26.5	9.8	38.2	18.9	5.0
RC0	66.0	49.6	33.5	37.5	22.6	1.8	42.6	27.7	16.6
RC1	72.9	54.6	36.0	43.6	26.2	6.9	37.8	19.2	6.8
RC2	68.4	54.6	35.1	42.2	27.5	5.5	35.2	17.9	5.4
RC3	71.0	52.0	35.0	37.5	22.8	11.3	42.3	25.2	11.6
RC4	66.8	50.4	34.3	39.5	25.5	13.4	41.5	24.1	11.6
n=28									
Max	92.9	59.5	41.3	67.6	28.8	20.0	68.0	30.7	21.6
Mean	74.4	54.1	32.9	43.0	24.2	6.3	40.9	21.8	9.4
Min	60.5	45.4	16.1	37.1	21.9	0.0	33.2	16.2	4.1
Without Outflows (n=20)									
Max	92.9	59.5	41.3	67.6	28.8	20.0	68.0	25.2	11.8
Mean	76.7	55.7	33.9	43.8	24.5	6.8	40.4	19.9	7.0
Min	60.5	50.4	16.1	37.1	22.6	0.0	33.2	16.2	4.1
Outflows only (n=8)									
Max	85.7	55.9	35.0	44.9	25.6	14.3	54.3	30.7	21.6
Mean	68.5	50.1	30.5	40.8	23.6	4.8	42.1	26.3	15.3
Min	60.8	45.4	22.3	37.5	21.9	0.0	33.7	21.8	10.9

Table 13 Monthly and annual summaries of precipitation (mm) in the Muskoka/Haliburton area

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hy Yr	Total
1978						90	77	217	164	114	106	116	78-79	1276
1979	108	41	69	108	68	81	86	120	99	151	164	74	79-80	1200
1980	103	45	118	107	52	136	173	112	90	128	100	114	80-81	1198
1981	29	107	54	85	72	91	32	122	154	78	64	57	81-82	988
1982	92	52	88	86	74	132	58	73	123	69	160	155	82-83	1213
1983	72	48	53	94	179	13	36	81	121	129	109	136	83-84	1004
1984	54	79	62	53	130	64	97	38	115	53	110	149	84-85	1100
1985	67	103	117	99	87	72	108	114	80	106	115	116	85-86	1073
1986	79	34	91	56	102	125	116	89	170	79	46	94	86-87	981
1987	37	34	83	39	68	70	36	73	60	100	82	106	87-88	947
1988	102	103	55	97	63	31	53	99	81	148	97	74	88-89	985
1989	94	66	105	42	96	88	10	34	83	66	170	34	89-90	874
1990	114	52	47	96	79	33	78	9	56	158	152	100	90-91	987
1991	67	42	114	92	87	25	130	42	90	143	61	86	91-92	867
1992	68	63	87	39	35	54	102	112	154	67	167	58	92-93	1035
1993	103	28	35	73	80	113	76	50	143	135	93	34	93-94	943
1994	80	38	27	41	115	86	112	87	76	69	131	48	94-95	989
1995	112	53	49	81	85	63	138	65	94	147	178	66	95-96	1137
1996	108	64	39	99	77	72	134	58	143	81	77	100	96-97	1142
1997	147	112	72	54	92	38	38	95	58	88	75	37	97-98	760
1998	107	22	127	49	27	79	65	47	57	38	64	71	98-99	696
1999	108	43	35	21	70	98	82	82	146	122	95	110	99-00	1063
2000	50	59	52	63	104	95	40	126	76	21	67	69	00-01	840
2001	70	115	43	26	93	90	44	68	162	142	65	97	01-02	1097
2002	49	90	112	79	99	73	40	90	44	93	78	66	02-03	804
2003	54	50	71	49	94	87	59	53	113	126	178	79	03-04	1066
2004	59	50	113	52	98	78	108	72	37	72	69	147	04-05	895
2005	79	47	35	116	36	122	41	73	94	27	161	84	05-06	994
2006	104	114	58	75	42	59	176	62	122	182	93	73	06-07	1078
2007	65	32	67	98	50									
Mean	81.9	61.5	71.6	71.3	81.1	78	80.8	81.5	104	101	108	87.8		1008
STD	27.4	28.6	30.0	27.1	31.0	31	43.2	39.1	39.0	42.0	41.3	33.6		

Table 14 Monthly and annual summaries of temperature (^{0} C) in the Muskoka/Haliburton area

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Hy Yr	Total
1978						15.4	18.6	18.8	12.4	5.5	0.6	-7.0	78-79	4.5
1979	-12.2	-14.6	-0.6	4.7	11.9	16.6	19.3	16.9	13.7	6.7	2.2	-5.0	79-80	5.1
1980	-9.5	-12.2	-4.7	5.2	12.2	13.1	18.8	19.4	12.5	5.0	-1.1	-12.6	80-81	4.0
1981	-15.8	-4.2	-2.9	5.7	10.2	15.9	18.6	17.5	12.4	5.1	0.7	-6.0	81-82	4.1
1982	-16.1	-10.5	-4.6	1.7	14.3	14.5	18.7	15.4	13.4	8.6	2.1	-2.6	82-83	5.5
1983	-8.5	-6.2	-1.7	3.8	8.7	16.2	19.5	19.2	15.0	7.0	0.4	-10.0	83-84	4.9
1984	-12.8	-3.5	-7.1	6.2	8.9	16.5	18.0	18.7	11.6	8.9	0.4	-3.9	84-85	5.2
1985	-12.9	-7.7	-3.1	4.2	11.5	13.9	17.7	16.5	13.9	7.6	0.3	-8.8	85-86	5.0
1986	-10.5	-9.4	-1.9	7.2	13.6	14.7	18.8	16.0	12.3	6.6	-1.3	-4.6	86-87	5.5
1987	-8.0	-8.7	-0.6	8.2	12.5	17.1	20.4	17.3	13.7	4.8	0.2	-3.8	87-88	5.3
1988	-9.3	-10.0	-4.7	4.3	13.3	15.7	20.4	18.6	12.6	5.2	2.1	-6.1	88-89	5.1
1989	-6.5	-9.3	-4.8	2.3	11.4	16.4	19.4	17.3	13.0	7.1	-0.5	-15.0	89-90	5.1
1990	-3.5	-6.3	-1.9	5.6	10.1	16.4	18.7	18.0	12.4	6.6	1.0	-4.8	90-91	5.8
1991	-10.2	-6.5	-1.9	5.6	14.2	17.8	18.7	18.5	11.9	7.6	0.0	-6.4	91-92	4.7
1992	-10.1	-8.1	-6.7	2.7	10.9	14.1	15.3	15.0	12.6	4.5	-0.8	-5.3	92-93	3.7
1993	-8.3	-13.1	-4.2	4.1	10.8	14.9	18.8	18.1	11.1	5.0	-0.5	-6.9	93-94	3.4
1994	-17.5	-12.7	-3.8	4.0	9.7	16.5	18.2	15.9	13.1	7.3	2.4	-4.4	94-95	5.2
1995	-6.2	-11.4	-1.0	1.3	10.7	18.0	18.7	18.8	11.0	8.8	-2.7	-10.0	95-96	4.0
1996	-10.6	-10.0	-5.5	1.8	9.8	16.5	17.0	17.6	14.1	6.9	-2.1	-2.6	96-97	4.4
1997	-11.9	-7.6	-4.9	2.4	7.6	17.1	18.0	16.0	12.5	6.4	-0.2	-4.8	97-98	6.2
1998	-6.8	-3.3	-1.8	5.8	15.1	16.3	18.0	18.2	14.0	7.7	1.2	-2.3	98-99	6.1
1999	-10.5	-6.1	-2.8	5.5	13.5	18.0	19.5	16.4	14.5	6.0	2.8	-5.4	99-00	5.9
2000	-10.8	-6.5	0.7	3.6	11.3	14.9	16.7	16.5	12.4	7.6	0.6	-10.7	00-01	4.7
2001	-8.8	-7.6	-3.5	5.1	12.9	16.6	17.5	19.3	13.1	7.5	3.8	-1.5	01-02	6.3
2002	-4.4	-6.0	-4.0	4.7	8.4	16.4	19.9	18.4	16.0	5.8	-0.7	-6.1	02-03	4.5
2003	-13.3	-11.9	-4.0	2.4	11.0	16.0	17.7	18.6	14.4	5.8	2.4	-4.3	03-04	5.3
2004	-14.6	-6.9	-1.1	4.1	11.1	14.9	18.3	16.3	15.4	7.9	2.0	-7.7	04-05	4.9
2005	-11.1	-7.3	-5.2	5.1	10.0	19.1	20.1	18.9	15.7	8.4	1.3	-6.7	05-06	6.4
2006	-5.2	-9.3	-3.5	5.8	12.5	17.2	19.7	17.8	12.3	5.7	2.7	-1.8	06-07	5.5
2007	-8.2	-11.8	-3.1	3.9	12.2									
Mean	-10.1	-8.6	-3.3	4.4	11.4	16.1	18.6	17.6	13.2	6.7	0.7	-6.1		5.0
STD	3.5	2.9	1.9	1.7	1.9	1.3	1.1	1.3	1.3	1.3	1.6	3.2		

Table 15 Annual lake evaporation (mm/yr) for eight study lakes, 1978-07

Year	Blue Chalk	Chub	Crosson	Dickie	Harp	Heney	Plastic	Red Chalk	Mean of 8 lakes
1978-79	637	641		633	635		494	650	615
1979-80	562	585		599	585		573	565	578
1980-81	510	513	503	500	504	518	508	516	509
1981-82	534	549	579	552	547	557	566	531	552
1982-83	570	571	586	572	577	580	563	565	573
1983-84	588	630	622	624	604	605	620	584	610
1984-85	539	534	540	538	537	526	535	524	534
1985-85	553	580	567	580	556	566	549	558	563
1986-87	587	584	591	598	591	575	585	570	585
1987-88	631	632	661	632	654	650	656	627	643
1988-89	575	586	588	621	590	620	608	585	597
1989-90	589	602	601	606	583	629	581	582	597
1990-91	614	627	632	626	593	608	599	628	616
1991-92	636	644	666	660	637	665	664	638	651
1992-93	499	519	489	506	519	508	523	493	507
1993-94	544	570		547	553		560	534	551
1994-95	513	537		515	522		542	574	534
1995-96	547	537		535	539		549	552	543
1996-97	495	499		502	481		487	493	493
1997-98	591	591		587	574		660	577	597
1998-99	546	541		580	578		598	541	564
1999-00	536	552		545	534		553	530	541
2000-01	417	419		523	408		419	408	432
2001-02				530	512		528		524
2002-03				639	614		633		629
2003-04				458	447		433		446
2004-05				561	516		523		533
2005-06				729	637		644		670
2006-07				661	560		589		603
Mean 1978-07	557	567	586	578	558	585	564	558	565

Table 16 Annual change in lake level (mm/yr) for eight study lakes, 1978-2007

Year	Blue Chalk	Chub	Crosson	Dickie	Harp	Heney	Plastic	Red Chalk	Mean of 8 lakes
1978-79									
1979-80									
1980-81	20	-65		49	102		84	-68	20
1981-82	-13	59		-14	-3		-7	47	12
1982-83	-61	-49	-12	83	49	-27	-11	134	13
1983-84	70	-40	88	16	11	8	64	-20	25
1984-85	-150	-50	-109	-22	-82	-23	-34	-66	-67
1985-85	37	29	-62	-16	90	-29	-116	37	-4
1986-87	-69	-7	68	-9	-12	34	-63	-82	-18
1987-88	-17	-15	-139	63	-32	-37	27	3	-18
1988-89	101	61	186	15	38	56	9	43	64
1989-90	-59	-85	4	32	-18	86	0	62	3
1990-91	-51	88	-273	-20	1	18	132	-50	-19
1991-92	-74	-89	106	-43	-20	-41	-122	-85	-46
1992-93	54	50	36	52	40	0	171	277	85
1993-94	-81	2		-25	-19		3	-204	-54
1994-95	18	-30		-9	29		45	-34	3
1995-96	6	130		40	-8		-64	45	25
1996-97	43	-97		-2	-1		32	11	-2
1997-98	-657	73		-99	-71		-299	-266	-220
1998-99	242	-48		133	40		38	20	71
1999-00	-350	-104		-90	23		-193	258	-76
2000-01	68	-258		-20	12		111	-215	-50
2001-02				10	10		-94		-25
2002-03									
2003-04									
2004-05									
2005-06									
2006-07									
Mean 1978-07	-44	-21	-10	6	8	4	-13	-7	-13

Table 17_1 Annual water balance for Blue Chalk Lake, 1978-2007. Individual supply and loss terms in 10^3 m^3/yr

	Supply Terms			Loss Terms					
Year	Precip	Inflow	Total Supply	Outflow	Evap	Storage	Total Loss	Balance	Balance (%)
1978-79	667.9	526.4	1194.3	961.8	333.6		1295.4	101.1	7.8
1979-80	628.4	602.6	1230.9	1028.3	294.1		1322.3	91.4	6.9
1980-81	627.4	507.6	1135.0	970.4	267.2	6.4	1244.0	109.0	8.8
1981-82	517.4	410.7	928.1	732.1	279.4	-4.2	1007.3	79.2	7.9
1982-83	635.2	650.1	1285.3	1091.3	298.2	-19.6	1369.9	84.6	6.2
1983-84	537.1	464.5	1001.6	677.4	307.9	22.5	1007.8	6.2	0.6
1984-85	579.6	554.3	1133.9	993.8	282.0	-48.2	1227.6	93.7	7.6
1985-85	559.3	488.8	1048.0	764.2	289.5	11.9	1065.5	17.5	1.6
1986-87	536.2	389.3	925.5	706.6	307.1	-22.2	991.5	66.0	6.7
1987-88	509.7	402.0	911.7	654.3	330.4	-5.5	979.2	67.5	6.9
1988-89	562.0	424.0	986.0	673.1	300.8	32.5	1006.4	20.3	2.0
1989-90	410.2	543.0	953.1	696.8	308.5	-19.0	986.3	33.2	3.4
1990-91	464.0	640.1	1104.1	821.0	321.5	-16.4	1126.1	21.9	1.9
1991-92	401.9	467.3	869.2	627.2	332.7	-23.8	936.1	66.9	7.1
1992-93	502.0	663.2	1165.3	949.3	261.3	17.4	1227.9	62.7	5.1
1993-94	499.6	441.6	941.2	711.5	284.9	-26.0	970.3	29.1	3.0
1994-95	501.2	484.4	985.6	794.9	268.6	5.8	1069.3	83.7	7.8
1995-96	566.6	566.3	1132.9	936.2	286.4	1.9	1224.6	91.7	7.5
1996-97	560.5	461.6	1022.1	729.8	259.3	13.8	1003.0	-19.1	-1.9
1997-98	361.8	324.4	686.2	555.6	309.2	-211.2	653.6	-32.6	-5.0
1998-99	332.3	235.6	567.9	268.7	285.8	77.8	632.3	64.4	10.2
1999-00	532.6	321.0	853.5	727.1	280.8	-112.5	895.4	41.9	4.7
2000-01	407.8	476.6	884.4	693.4	218.0	21.9	933.3	48.9	5.2
2001-02									
2002-03									
2003-04									
2004-05									
2005-06									
2006-07									
Overall Balance									
1978-2007	11900.5	11045.3	22945.8	17764.5	6707.3	-296.7	24175.1	1229.3	5.1

Table 17_2 Annual water balance for Chub Lake, 1978-2007. Individual supply and loss terms in 10^3 m^3/yr

	Supply Terms			Loss Terms					
Year	Precip	Inflow	Total Supply	Outflow	Evap	Storage	Total Loss	Balance	Balance (%)
1978-79	439.0	1354.3	1793.3	1636.9	220.6		1857.4	64.2	3.5
1979-80	413.0	1498.3	1911.3	1804.2	201.4		2005.6	94.3	4.7
1980-81	412.4	1583.4	1995.8	1771.7	176.5	-20.9	1927.3	-68.6	-3.6
1981-82	340.1	1200.3	1540.4	1260.2	189.0	19.0	1468.1	-72.2	-4.9
1982-83	417.5	1644.4	2061.9	1961.7	196.4	-15.7	2142.4	80.5	3.8
1983-84	353.0	1187.4	1540.5	1420.3	216.9	-12.9	1624.4	83.9	5.2
1984-85	381.0	1558.4	1939.3	1839.7	183.9	-16.1	2007.5	68.2	3.4
1985-85	367.6	1184.9	1552.5	1396.3	199.5	9.3	1605.1	52.6	3.3
1986-87	352.4	950.8	1303.2	1178.5	201.1	-2.2	1377.4	74.1	5.4
1987-88	335.0	1220.8	1555.9	1311.6	217.4	-4.8	1524.2	-31.7	-2.1
1988-89	369.4	1079.5	1448.9	1268.2	201.5	19.6	1489.3	40.4	2.7
1989-90	269.6	1071.7	1341.3	1243.4	207.2	-27.3	1423.3	82.0	5.8
1990-91	305.0	1265.8	1570.8	1470.7	215.8	28.3	1714.8	144.0	8.4
1991-92	264.2	1088.5	1352.7	1217.5	221.6	-28.6	1410.5	57.7	4.1
1992-93	330.0	1642.5	1972.5	1664.6	178.7	16.1	1859.3	-113.2	-6.1
1993-94	328.4	1171.3	1499.6	1387.3	196.3	0.6	1584.3	84.7	5.3
1994-95	329.4	1439.5	1768.9	1623.0	184.8	-9.6	1798.1	29.2	1.6
1995-96	372.5	1665.4	2037.8	1824.5	184.9	41.8	2051.2	13.4	0.7
1996-97	368.4	1820.0	2188.5	2151.6	171.6	-31.2	2292.0	103.6	4.5
1997-98	237.8	897.9	1135.7	874.8	203.4	23.5	1101.7	-34.0	-3.1
1998-99	218.4	836.6	1055.1	815.0	186.1	-15.4	985.7	-69.4	-7.0
1999-00	350.1	1383.8	1733.9	1420.7	189.8	-33.4	1577.1	-156.7	-9.9
2000-01	268.1	913.1	1181.2	1167.9	144.1	-82.9	1229.1	47.9	3.9
2001-02									
2002-03									
2003-04									
2004-05									
2005-06									
2006-07									
Overall Balance									
1978-2007	7822.3	29658.8	37481.1	33710.5	4488.3	-143.0	38055.8	574.8	1.5

Table 17_3 Annual water balance for Crosson Lake, 1978-2007. Individual supply and loss terms in 10^3 m^3/yr

	Supply Terms			Loss Terms					
Year	Precip	Inflow	Total Supply	Outflow	Evap	Storage	Total Loss	Balance	Balance (%)
1978-79									
1979-80									
1980-81	680.0	3383.0	4063.0	3949.3	285.1		4234.4	171.4	4.0
1981-82	560.8	2412.8	2973.6	2817.8	328.5		3146.3	172.7	5.5
1982-83	688.4	3731.5	4419.9	4297.6	332.6	-3.9	4626.4	206.5	4.5
1983-84	562.7	2930.1	3492.8	2905.0	352.7	28.3	3286.0	-206.9	-6.3
1984-85	640.3	3677.1	4317.4	4216.5	306.5	-35.0	4487.9	170.5	3.8
1985-85	574.1	2887.7	3461.8	3041.4	321.7	-19.9	3343.2	-118.6	-3.5
1986-87	548.8	2325.9	2874.7	2741.5	335.1	21.9	3098.4	223.7	7.2
1987-88	542.6	2471.8	3014.4	2566.2	374.9	-44.7	2896.4	-118.0	-4.1
1988-89	550.1	2654.7	3204.8	2875.8	333.4	59.8	3269.0	64.2	2.0
1989-90	548.6	2734.8	3283.4	2899.2	340.7	1.3	3241.2	-42.2	-1.3
1990-91	599.1	2814.1	3413.2	3355.3	358.6	-87.7	3626.2	213.0	5.9
1991-92	522.9	2198.6	2721.5	2475.3	378.0	34.1	2887.4	165.9	5.7
1992-93	648.8	3210.8	3859.6	3802.0	277.3	11.6	4090.9	231.2	5.7
1993-94									
1994-95									
1995-96									
1996-97									
1997-98									
1998-99									
1999-00									
2000-01									
2001-02									
2002-03									
2003-04									
2004-05									
2005-06									
2006-07									
Overall Balance 1978-2007	7667.3	37432.9	45100.2	41942.9	4325.2	-34.4	46233.7	1133.5	2.5

Table 17_4 Annual water balance for Dickie Lake, 1978-2007. Individual supply and loss terms in 10^3 m^3/yr

	Supply Terms			Loss Terms					
Year	Precip	Inflow	Total Supply	Outflow	Evap	Storage	Total Loss	Balance	Balance (%)
1978-79	1194.1	2318.9	3513.1	2685.2	592.6		3277.8	-235.3	-7.2
1979-80	1123.5	2690.4	3813.9	2909.0	560.6		3469.6	-344.3	-9.9
1980-81	1121.7	2861.4	3983.1	3536.3	468.2	45.9	4050.4	67.3	1.7
1981-82	925.0	2149.4	3074.4	2449.9	517.1	-13.1	2953.9	-120.5	-4.1
1982-83	1135.6	2974.4	4110.1	3452.2	535.7	77.7	4065.6	-44.5	-1.1
1983-84	928.3	2107.2	3035.5	2498.4	584.1	15.0	3097.5	62.0	2.0
1984-85	1056.3	2543.4	3599.6	3230.3	503.7	-20.6	3713.4	113.8	3.1
1985-85	947.0	2034.1	2981.2	2492.0	542.7	-15.0	3019.8	38.6	1.3
1986-87	905.3	1617.1	2522.4	1860.5	559.7	-8.4	2411.8	-110.6	-4.6
1987-88	895.1	1843.5	2738.6	2018.5	591.3	59.0	2668.8	-69.8	-2.6
1988-89	907.5	1802.0	2709.5	1930.9	581.3	14.0	2526.2	-183.2	-7.3
1989-90	905.0	1870.2	2775.2	1831.1	567.0	30.0	2428.1	-347.2	-14.3
1990-91	988.3	2389.4	3377.7	2492.9	585.6	-18.7	3059.8	-317.9	-10.4
1991-92	862.6	1880.8	2743.4	2181.3	618.1	-40.2	2759.1	15.7	0.6
1992-93	1070.3	2446.2	3516.5	3052.4	474.0	48.7	3575.1	58.6	1.6
1993-94	923.1	2092.2	3015.3	2515.6	512.0	-23.4	3004.2	-11.1	-0.4
1994-95	932.5	2239.3	3171.8	2871.3	482.1	-8.4	3345.0	173.2	5.2
1995-96	1038.9	2409.5	3448.4	2908.4	500.6	37.4	3446.4	-2.0	-0.1
1996-97	1038.6	2580.6	3619.2	3198.1	469.5	-1.9	3665.7	46.5	1.3
1997-98	784.1	1589.2	2373.3	1988.0	549.1	-92.7	2444.4	71.1	2.9
1998-99	709.3	753.1	1462.4	836.8	543.2	124.5	1504.5	42.1	2.8
1999-00	987.3	2013.9	3001.2	2575.5	510.1	-84.2	3001.3	0.1	0.0
2000-01	859.7	1911.3	2771.0	2435.9	489.3	-18.7	2906.5	135.5	4.7
2001-02	1020.3	2375.2	3395.5	3116.2	496.5	9.4	3622.1	226.5	6.3
2002-03	792.3	1524.5	2316.8	1884.2	598.3		2482.5	165.7	6.7
2003-04	866.7	2378.9	3245.7	3023.6	428.7		3452.3	206.6	6.0
2004-05	838.9	1817.2	2656.1	2443.1	525.1		2968.2	312.1	10.5
2005-06	967.2	2379.8	3347.0	2760.9	682.5		3443.4	96.5	2.8
2006-07	1272.1	2067.7	3339.9	2649.1	618.8		3267.9	-72.0	-2.2
Overall Balance									
1978-2007	27996.9	61660.7	89657.6	73827.6	15687.6	116.1	89631.2	-26.4	0.0

Table 17_5 Annual water balance for Harp Lake, 1978-2007. Individual supply and loss terms in 10^3 m^3/yr

	Supply Terms			Loss Terms					
Year	Precip	Inflow	Total Supply	Outflow	Evap	Storage	Total Loss	Balance	Balance (%)
1978-79	910.7	3085.7	3996.3	3551.1	453.1		4004.2	7.9	0.2
1979-80	856.8	3223.5	4080.3	3399.9	417.3		3817.2	-263.1	-6.9
1980-81	855.4	3252.8	4108.2	3301.9	359.5	72.8	3734.2	-374.0	-10.0
1981-82	705.4	2960.8	3666.2	2991.5	390.4	-2.1	3379.8	-286.5	-8.5
1982-83	866.1	3230.7	4096.8	3526.7	411.6	35.0	3973.3	-123.5	-3.1
1983-84	707.9	2398.9	3106.8	2569.3	430.9	7.9	3008.1	-98.7	-3.3
1984-85	792.2	3367.5	4159.7	3707.6	383.6	-58.5	4032.7	-127.0	-3.1
1985-85	848.6	3262.0	4110.6	3626.1	396.8	64.2	4087.2	-23.4	-0.6
1986-87	676.8	2061.7	2738.4	2407.9	421.8	-8.6	2821.1	82.6	2.9
1987-88	684.0	2304.4	2988.4	2429.1	466.8	-22.8	2873.0	-115.4	-4.0
1988-89	687.2	2364.8	3051.9	2497.4	421.2	27.1	2945.7	-106.3	-3.6
1989-90	598.9	2070.5	2669.4	2297.7	416.4	-12.8	2701.3	31.9	1.2
1990-91	716.2	2688.3	3404.5	2978.6	423.6	0.7	3402.9	-1.6	0.0
1991-92	626.1	2149.8	2775.9	2341.9	454.4	-14.3	2781.9	6.1	0.2
1992-93	712.2	2978.6	3690.8	3222.6	370.2	28.6	3621.3	-69.4	-1.9
1993-94	650.6	2488.2	3138.8	2594.8	394.5	-13.6	2975.7	-163.1	-5.5
1994-95	742.6	2840.3	3582.9	3219.1	372.3	20.7	3612.1	29.2	0.8
1995-96	891.7	3824.3	4716.0	4137.1	384.7	-5.7	4516.1	-199.9	-4.4
1996-97	846.5	3604.6	4451.1	3866.2	343.2	-0.7	4208.7	-242.4	-5.8
1997-98	530.9	1544.4	2075.2	1782.7	410.0	-50.7	2142.1	66.8	3.1
1998-99	488.3	1322.6	1810.9	1468.9	412.8	28.6	1910.2	99.3	5.2
1999-00	743.1	2236.1	2979.2	2808.8	380.8	16.4	3206.0	226.9	7.1
2000-01	678.5	1741.6	2420.1	2204.1	291.6	8.6	2504.3	84.2	3.4
2001-02	819.2	3166.1	3985.4	3291.7	365.8	7.1	3664.6	-320.8	-8.8
2002-03	625.4	1471.3	2096.6	1483.3	438.3		1921.6	-175.0	-9.1
2003-04	765.8	2391.2	3157.0	3136.1	319.4		3455.4	298.4	8.6
2004-05	574.0	1852.5	2426.5	2083.9	368.4		2452.3	25.8	1.1
2005-06	688.7	2128.9	2817.6	2149.9	454.9		2604.8	-212.8	-8.2
2006-07	759.3	2053.2	2812.5	2715.3	399.5		3114.7	302.3	9.7
Overall Balance									
1978-2007	21048.7	74065.3	95114.0	81791.1	11553.6	127.8	93472.5	-1641.5	-1.8

Table 17_6 Annual water balance for Heney Lake, 1978-2007. Individual supply and loss terms in 10^3 m^3/yr

	Supply Terms			Loss Terms					
Year	Precip	Inflow	Total Supply	Outflow	Evap	Storage	Total Loss	Balance	Balance (%)
1978-79									
1979-80									
1980-81	256.1	544.0	800.1	657.3	110.8		768.0	-32.1	-4.2
1981-82	211.2	366.7	577.9	418.0	119.0		536.9	-40.9	-7.6
1982-83	259.3	502.6	761.9	614.2	124.0	-8.7	729.6	-32.3	-4.4
1983-84	211.9	401.0	612.9	444.6	129.2	2.6	576.4	-36.6	-6.3
1984-85	241.2	455.2	696.4	628.9	112.5	-7.4	734.0	37.6	5.1
1985-85	216.2	377.8	594.0	483.5	120.9	-9.3	595.1	1.1	0.2
1986-87	206.7	283.0	489.7	371.1	122.8	10.9	504.8	15.1	3.0
1987-88	204.4	330.9	535.3	402.4	139.0	-11.9	529.5	-5.7	-1.1
1988-89	207.2	357.3	564.5	441.5	132.5	18.0	592.0	27.5	4.7
1989-90	206.6	333.2	539.8	332.5	134.5	27.6	494.7	-45.1	-9.1
1990-91	225.6	393.0	618.6	469.1	129.8	5.8	604.7	-13.9	-2.3
1991-92	196.9	322.1	519.1	358.5	142.0	-13.2	487.3	-31.8	-6.5
1992-93	244.4	452.6	696.9	603.8	108.6	0.0	712.4	15.5	2.2
1993-94									
1994-95									
1995-96									
1996-97									
1997-98									
1998-99									
1999-00									
2000-01									
2001-02									
2002-03									
2003-04									
2004-05									
2005-06									
2006-07									
Overall Balance									
1978-2007	2887.7	5119.3	8007.0	6225.4	1625.7	14.5	7865.6	-141.5	-1.8

Table 17_7 Annual water balance for Plastic Lake, 1978-2007. Individual supply and loss terms in 10^3 m^3/yr

	Supply Terms			Loss Terms					
Year	Precip	Inflow	Total Supply	Outflow	Evap	Storage	Total Loss	Balance	Balance (%)
1978-79	410.0	439.4	849.4	613.2	158.7		772.0	-77.4	-10.0
1979-80	385.8	516.3	902.1	720.4	184.1		904.4	2.4	0.3
1980-81	385.2	515.8	901.0	628.0	163.3	27.0	818.2	-82.8	-10.1
1981-82	317.6	456.9	774.6	567.7	181.8	-2.2	747.3	-27.3	-3.7
1982-83	390.0	770.0	1159.9	909.3	181.1	-3.5	1086.8	-73.1	-6.7
1983-84	323.1	533.1	856.3	607.1	199.1	20.6	826.8	-29.5	-3.6
1984-85	338.8	604.9	943.7	762.5	171.9	-10.9	923.4	-20.3	-2.2
1985-85	327.1	479.6	806.6	614.7	176.3	-37.3	753.7	-52.9	-7.0
1986-87	317.4	440.0	757.4	630.3	188.0	-20.2	798.1	40.6	5.1
1987-88	288.6	428.0	716.7	507.1	210.8	8.7	726.6	9.9	1.4
1988-89	303.4	473.8	777.2	555.8	195.5	2.9	754.1	-23.1	-3.1
1989-90	288.3	495.8	784.1	579.5	186.9	0.0	766.3	-17.8	-2.3
1990-91	324.5	551.6	876.2	664.6	192.6	42.4	899.7	23.5	2.6
1991-92	296.4	419.8	716.2	549.0	213.3	-39.2	723.2	7.0	1.0
1992-93	344.3	575.6	919.9	724.2	168.2	55.0	947.4	27.4	2.9
1993-94	285.3	425.6	710.9	473.7	180.0	1.0	654.6	-56.3	-8.6
1994-95	301.5	476.5	778.0	599.8	174.3	14.5	788.6	10.6	1.3
1995-96	354.6	652.0	1006.6	770.0	176.6	-20.6	926.1	-80.5	-8.7
1996-97	386.0	717.6	1103.7	938.4	156.6	10.3	1105.3	1.7	0.1
1997-98	254.6	351.9	606.5	447.3	212.1	-96.1	563.3	-43.2	-7.7
1998-99	219.4	232.4	451.8	245.1	192.2	12.2	449.5	-2.3	-0.5
1999-00	364.9	513.2	878.1	679.4	177.6	-62.0	794.9	-83.1	-10.5
2000-01	301.4	403.8	705.3	555.2	134.5	35.7	725.4	20.1	2.8
2001-02	352.3	520.1	872.4	635.5	169.8	-30.2	775.1	-97.3	-12.5
2002-03	261.6	382.7	644.4	428.6	203.5		632.1	-12.3	-1.9
2003-04	345.2	543.3	888.4	818.6	139.1		957.7	69.3	7.2
2004-05	313.2	378.1	691.4	485.9	168.2		654.1	-37.2	-5.7
2005-06	312.9	509.0	822.0	583.9	206.9		790.8	-31.2	-3.9
2006-07	277.3	401.4	678.7	474.9	189.4		664.4	-14.3	-2.2
Overall Balance									
1978-2007	9370.9	14208.4	23579.2	17769.8	5252.3	-92.2	22929.9	-649.4	-2.8

Table 17_8 Annual water balance for Red Chalk Lake, 1978-2007. Individual supply and loss terms in 10^3 m^3/yr

	Supply Terms			Loss Terms					
Year	Precip	Inflow	Total Supply	Outflow	Evap	Storage	Total Loss	Balance	Balance (%)
1978-79	728.9	3506.1	4235.0	4045.0	371.3		4416.3	181.4	4.1
1979-80	685.7	3502.8	4188.6	3964.1	322.8		4286.9	98.3	2.3
1980-81	684.6	3223.6	3908.3	3722.1	294.7	-21.9	3995.0	86.7	2.2
1981-82	564.6	2448.2	3012.8	2986.7	303.3	15.1	3305.1	292.4	8.8
1982-83	693.2	3758.9	4452.1	4357.9	322.6	43.1	4723.6	271.5	5.7
1983-84	586.2	2492.3	3078.4	2972.3	333.9	-6.4	3299.8	221.4	6.7
1984-85	632.5	3367.0	3999.5	3635.1	299.6	-21.2	3913.4	-86.0	-2.2
1985-85	610.3	2685.1	3295.4	2956.7	318.7	11.9	3287.3	-8.1	-0.2
1986-87	585.1	2418.6	3003.8	2654.8	325.6	-26.4	2954.0	-49.8	-1.7
1987-88	556.2	2395.9	2952.1	2554.7	358.5	1.0	2914.1	-38.0	-1.3
1988-89	613.3	2527.5	3140.8	2738.0	334.2	13.8	3085.9	-54.9	-1.8
1989-90	447.6	2457.0	2904.6	2709.6	332.7	19.9	3062.3	157.6	5.1
1990-91	506.4	2912.3	3418.7	3237.0	358.8	-16.1	3579.7	161.0	4.5
1991-92	438.6	2312.2	2750.9	2646.3	364.5	-27.3	2983.5	232.6	7.8
1992-93	547.9	3553.2	4101.0	3701.7	281.4	89.0	4072.2	-28.9	-0.7
1993-94	545.2	2503.2	3048.4	2916.8	304.9	-65.6	3156.2	107.8	3.4
1994-95	547.0	2833.0	3380.0	3242.0	327.9	-10.9	3559.0	179.1	5.0
1995-96	618.4	3425.9	4044.2	3654.8	315.5	14.5	3984.8	-59.5	-1.5
1996-97	611.7	3543.5	4155.2	3939.6	281.4	3.5	4224.5	69.3	1.6
1997-98	394.8	2134.3	2529.2	2494.1	329.4	-85.5	2738.0	208.8	7.6
1998-99	362.7	1044.1	1406.8	1126.1	309.0	6.4	1441.5	34.7	2.4
1999-00	581.2	2756.4	3337.6	2961.2	302.5	82.9	3346.7	9.1	0.3
2000-01	445.0	2258.5	2703.5	2645.0	233.3	-69.1	2809.2	105.7	3.8
2001-02									
2002-03									
2003-04									
2004-05									
2005-06									
2006-07									
Overall Balance									
1978-2007	12987.1	64059.7	77046.8	71861.6	7326.5	-49.2	79138.9	2092.1	2.6

Table 18 Flushing rate and residence time (years) for eight study lakes, 1978-2007

Year	Flushing Rate							
	BC	CB	CN	DE	HP	HY	PC	RC
1978-79	4.65	1.86		1.74	2.68		4.12	2.00
1979-80	4.35	1.69		1.60	2.80		3.50	2.05
1980-81	4.60	1.72	1.32	1.32	2.88	1.07	4.02	2.18
1981-82	6.10	2.41	1.85	1.90	3.18	1.69	4.45	2.72
1982-83	4.09	1.55	1.21	1.35	2.70	1.15	2.78	1.86
1983-84	6.60	2.14	1.80	1.87	3.70	1.59	4.16	2.73
1984-85	4.50	1.65	1.24	1.44	2.56	1.12	3.31	2.23
1985-85	5.85	2.18	1.71	1.87	2.62	1.46	4.11	2.74
1986-87	6.32	2.58	1.90	2.51	3.95	1.90	4.00	3.05
1987-88	6.83	2.32	2.03	2.31	3.91	1.75	4.98	3.17
1988-89	6.64	2.40	1.81	2.42	3.81	1.60	4.54	2.96
1989-90	6.41	2.45	1.80	2.55	4.14	2.12	4.36	2.99
1990-91	5.44	2.07	1.55	1.87	3.19	1.50	3.80	2.51
1991-92	7.12	2.50	2.11	2.14	4.06	1.97	4.60	3.06
1992-93	4.71	1.83	1.37	1.53	2.95	1.17	3.49	2.19
1993-94	6.28	2.19		1.85	3.66		5.33	2.78
1994-95	5.62	1.87		1.62	2.95		4.21	2.50
1995-96	4.77	1.67		1.60	2.30		3.28	2.22
1996-97	6.12	1.41		1.46	2.46		2.69	2.06
1997-98	8.04	3.48		2.35	5.33		5.64	3.25
1998-99	16.63	3.73		5.57	6.47		10.30	7.20
1999-00	6.15	2.14		1.81	3.38		3.72	2.74
2000-01	6.44	2.60		1.92	4.31		4.55	3.07
2001-02				1.50	2.89		3.97	
2002-03				2.48	6.41		5.89	
2003-04				1.54	3.03		3.08	
2004-05				1.91	4.56		5.19	
2005-06				1.69	4.42		4.32	
2006-07				1.76	3.50		5.31	
Mean 1978-07	6.27	2.19	1.67	1.98	3.61	1.54	4.40	2.79

Table 18 (continued…)

Year	Residence Time							
	BC	CB	CN	DE	HP	HY	PC	RC
1978-79	3.45	1.64		1.42	2.37		3.27	1.84
1979-80	3.38	1.52		1.34	2.49		2.79	1.89
1980-81	3.59	1.58	1.23	1.15	2.55	0.92	3.08	2.03
1981-82	4.44	2.07	1.66	1.58	2.81	1.31	3.38	2.45
1982-83	3.26	1.42	1.13	1.15	2.39	0.97	2.32	1.72
1983-84	4.43	1.87	1.59	1.51	3.16	1.22	3.05	2.46
1984-85	3.64	1.52	1.16	1.26	2.36	0.96	2.73	2.07
1985-85	4.19	1.90	1.56	1.54	2.33	1.18	3.35	2.47
1986-87	4.51	2.21	1.68	1.93	3.37	1.40	3.16	2.75
1987-88	4.56	2.00	1.80	1.75	3.31	1.33	3.47	2.78
1988-89	4.44	2.04	1.60	1.85	3.23	1.19	3.35	2.63
1989-90	4.53	2.14	1.61	1.92	3.52	1.43	3.29	2.65
1990-91	3.97	1.77	1.44	1.52	2.79	1.17	2.81	2.27
1991-92	4.77	2.16	1.81	1.69	3.42	1.45	3.49	2.72
1992-93	3.64	1.64	1.28	1.30	2.63	0.99	2.66	1.99
1993-94	4.60	1.92		1.55	3.19		3.86	2.57
1994-95	4.18	1.69		1.39	2.63		3.20	2.28
1995-96	3.65	1.48		1.35	2.11		2.73	2.04
1996-97	4.45	1.33		1.27	2.26		2.28	1.92
1997-98	6.84	2.76		1.91	4.44		4.48	2.96
1998-99	7.07	3.09		3.10	4.98		5.62	5.63
1999-00	4.99	1.93		1.55	2.97		3.18	2.42
2000-01	4.79	2.48		1.61	3.80		3.48	2.89
2001-02				1.29	2.59		3.26	
2002-03				1.88	4.95		3.99	
2003-04				1.35	2.75		2.64	
2004-05				1.57	3.88		3.86	
2005-06				1.35	3.65		3.19	
2006-07				1.43	3.05		3.80	
Mean 1978-07	4.41	1.92	1.50	1.57	3.10	1.19	3.30	2.50

Figure 1 Study area map, with locations of study lakes and meteorological sites

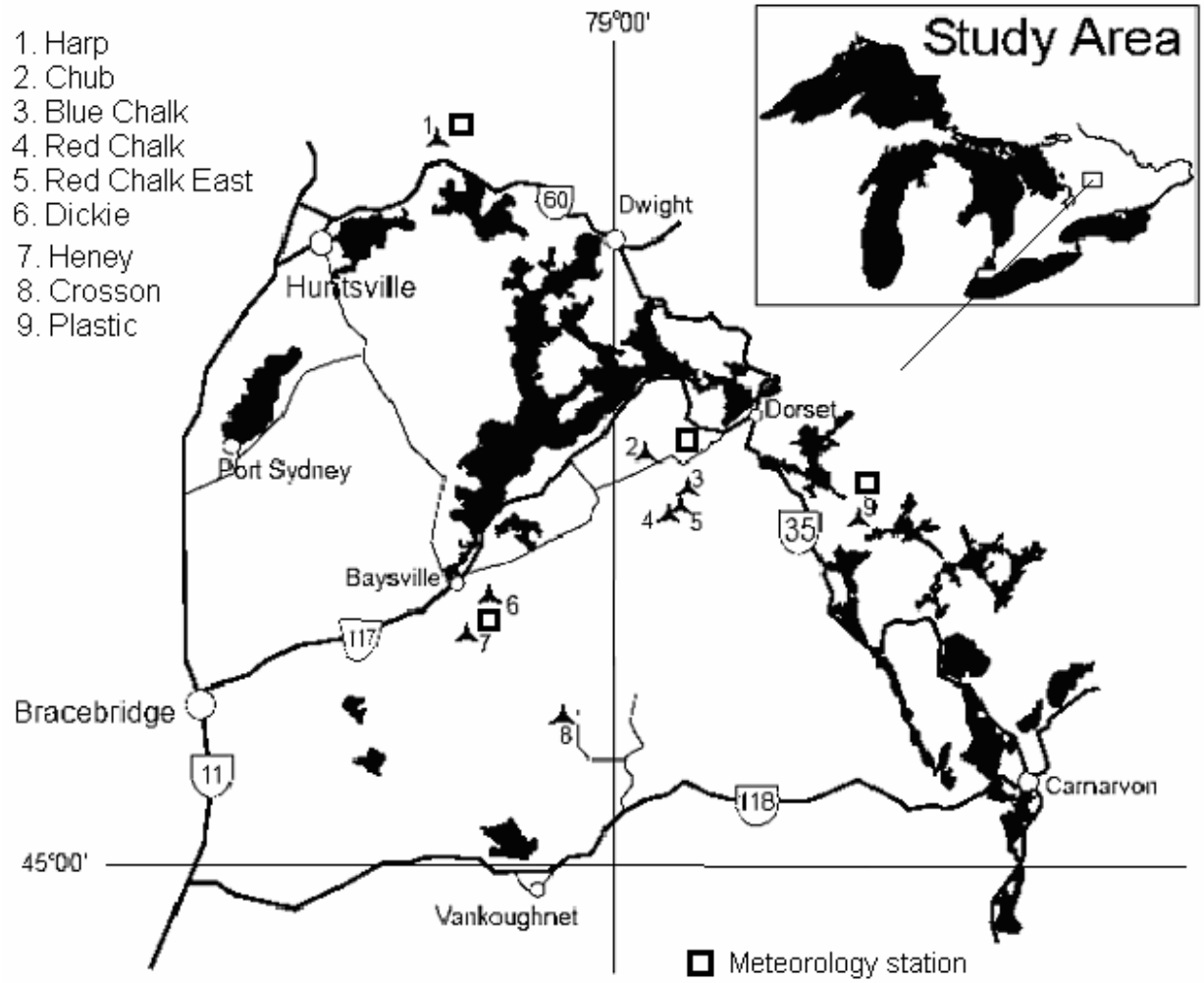
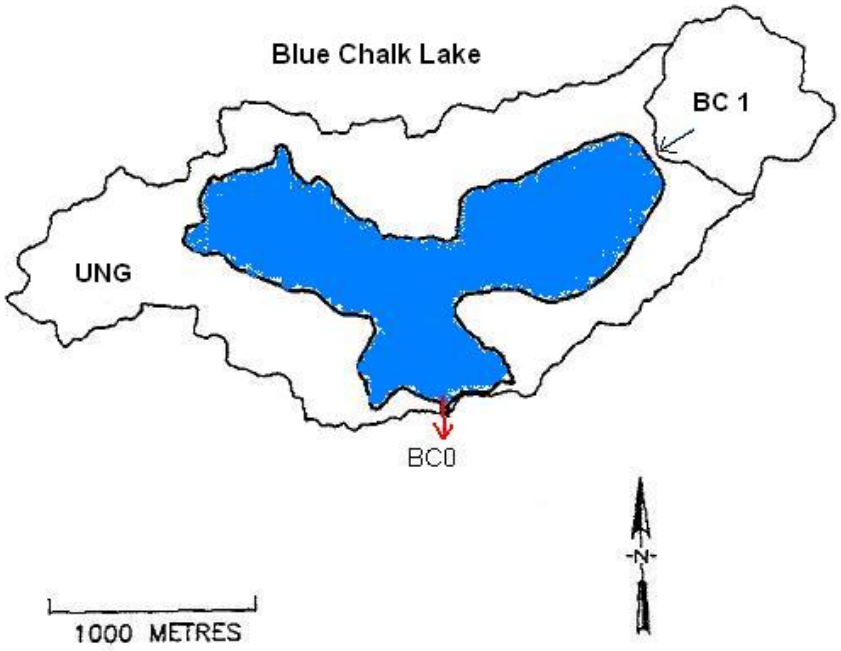


Figure 2 Lakes, their sub-catchments, and stream flow gauges



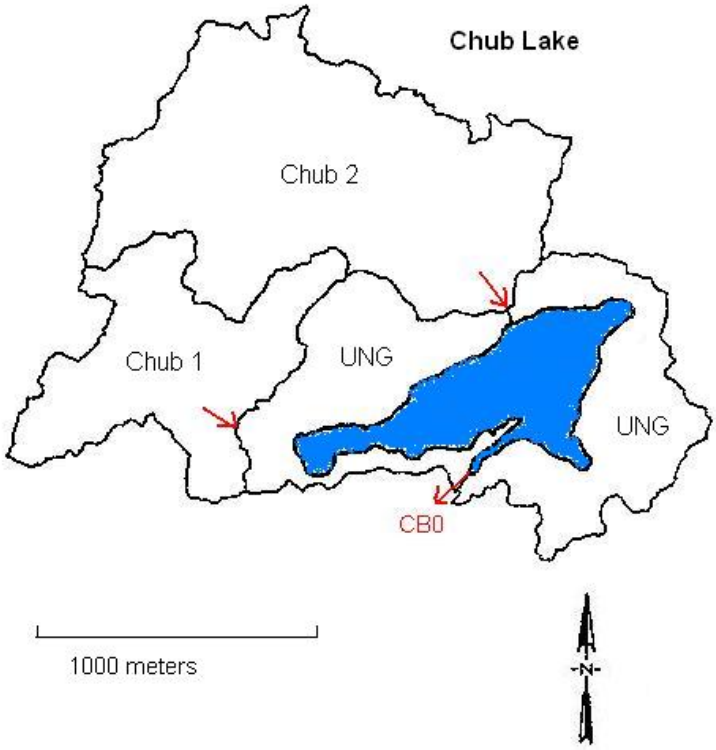
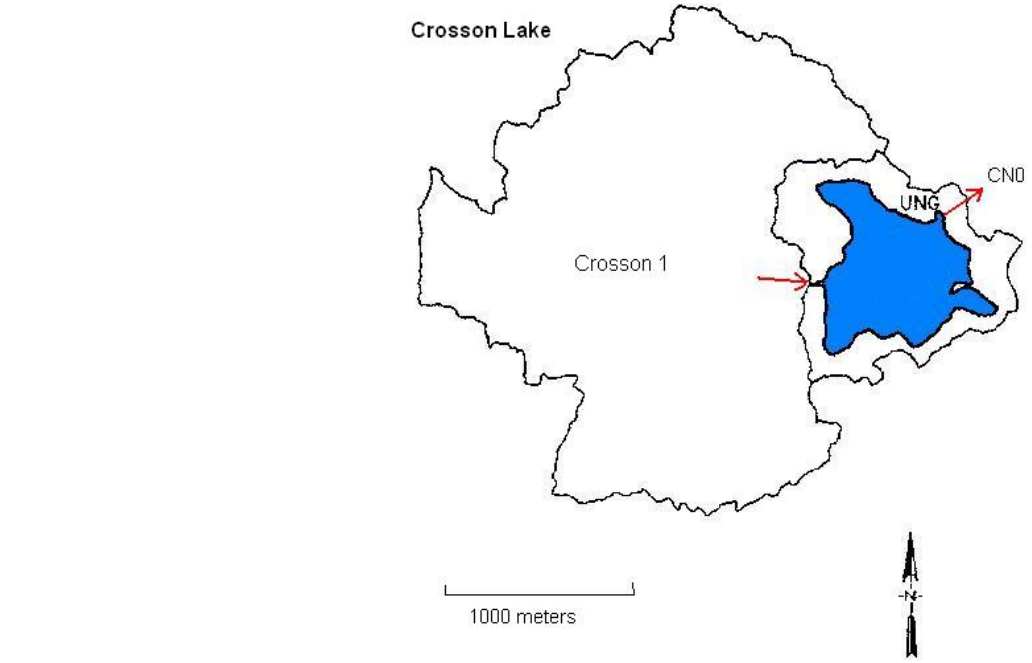
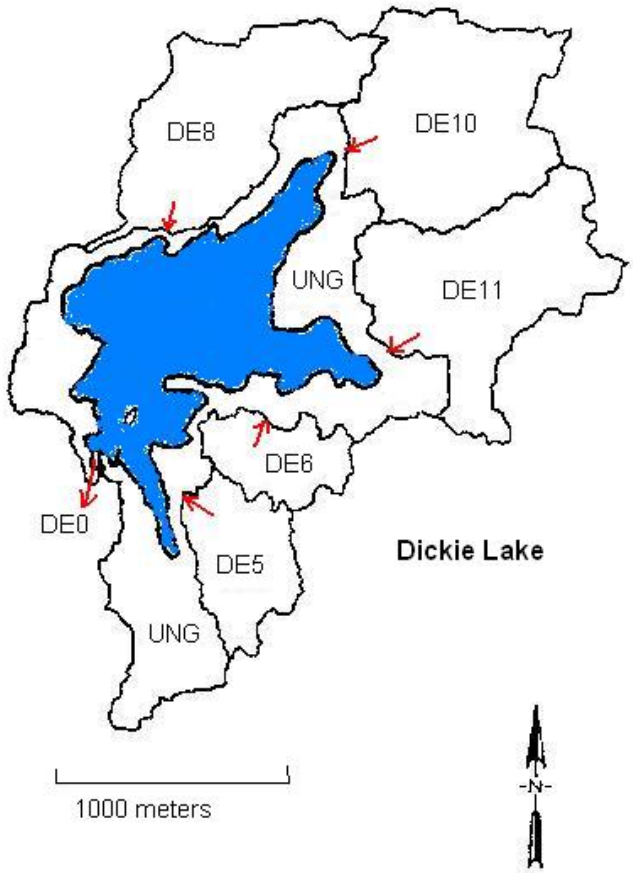


Figure 2 (continued)





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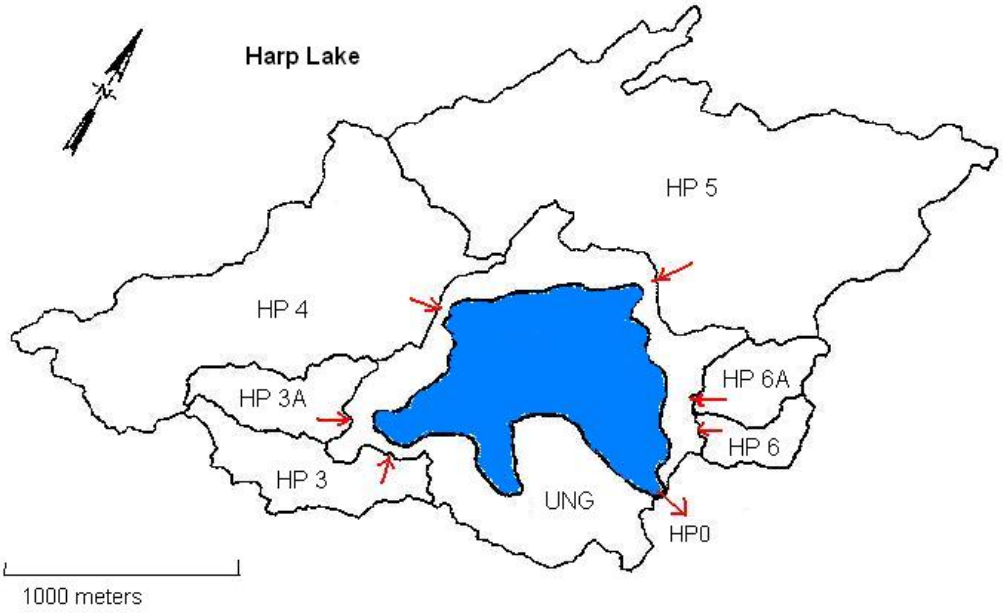

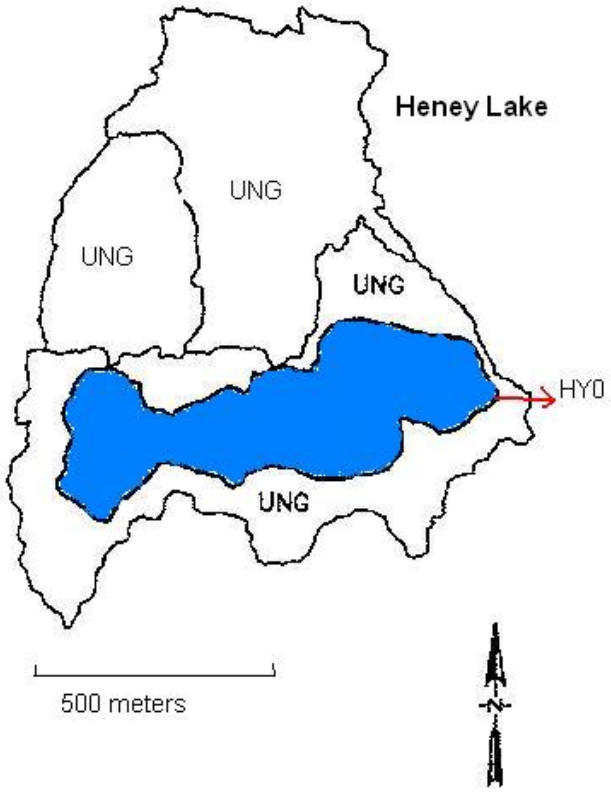

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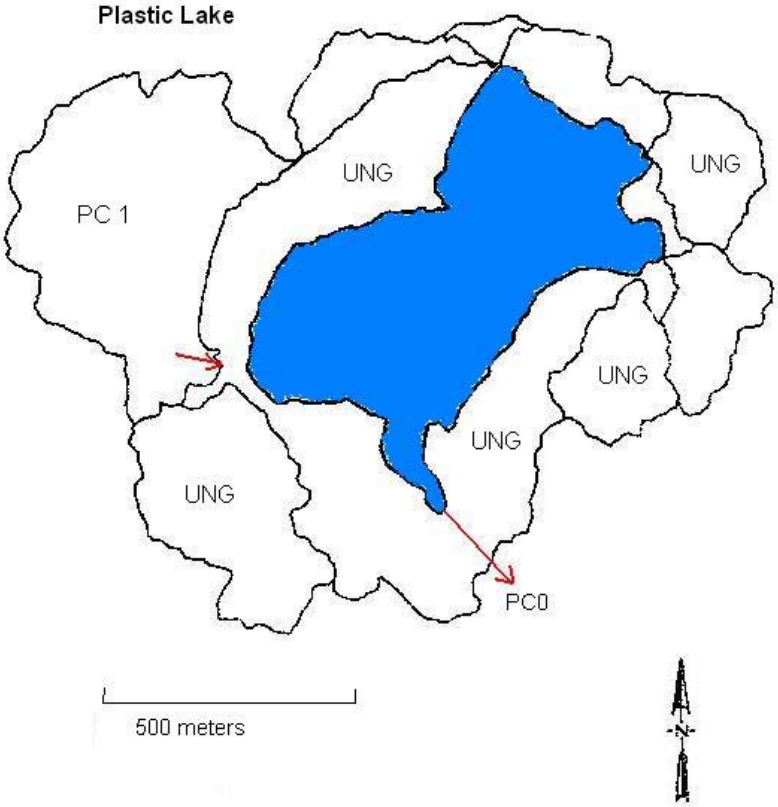


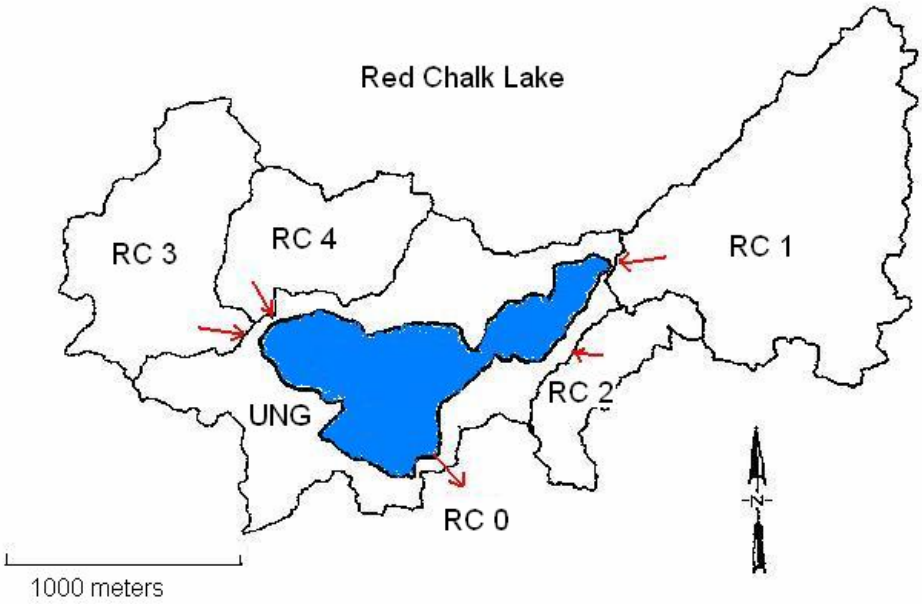


Figure 3 Muskoka/Haliburton Monthly Total Precipitation (mm/m)

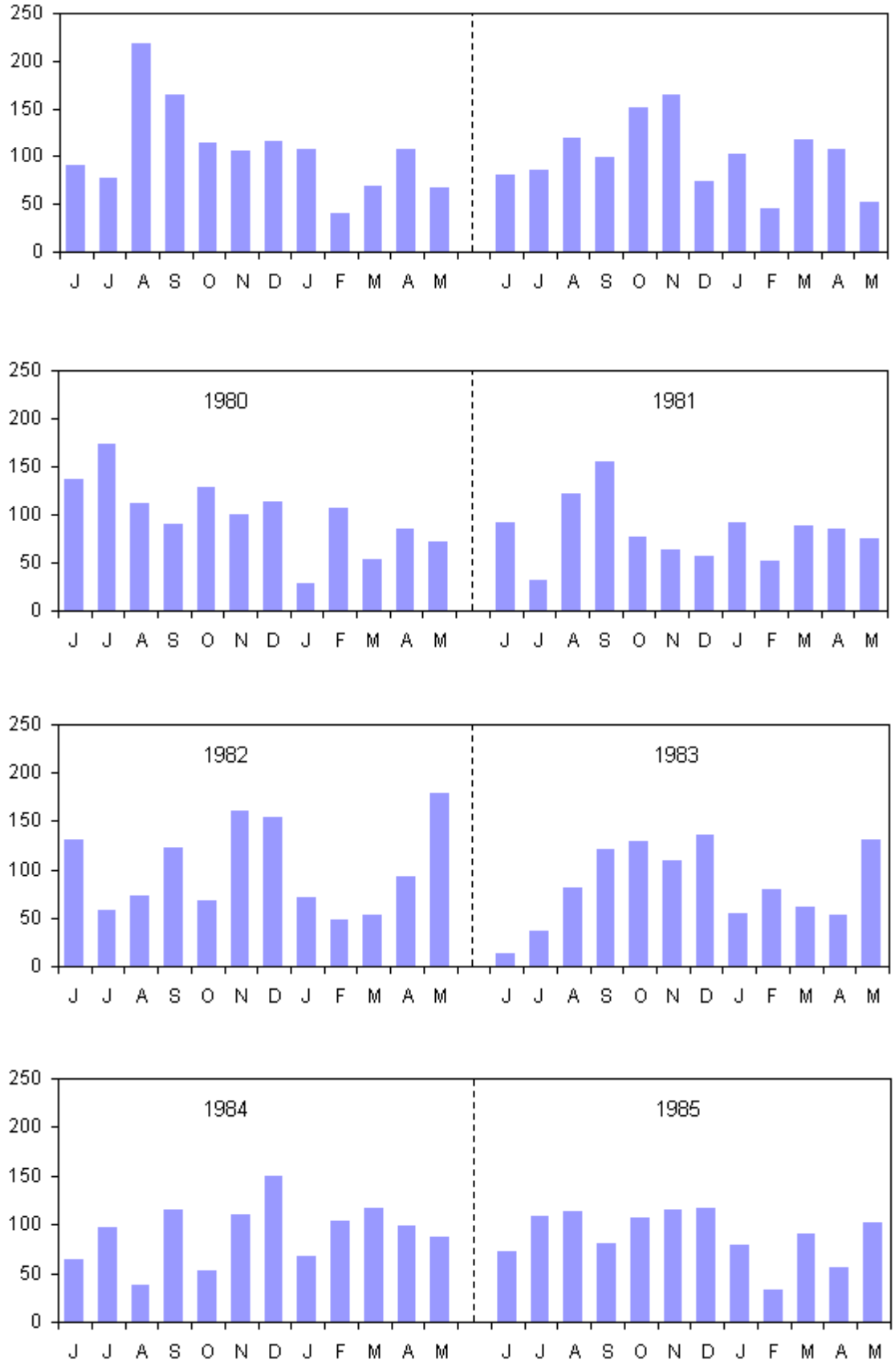


Figure 3 Muskoka/Haliburton Monthly Total Precipitation (mm/m)

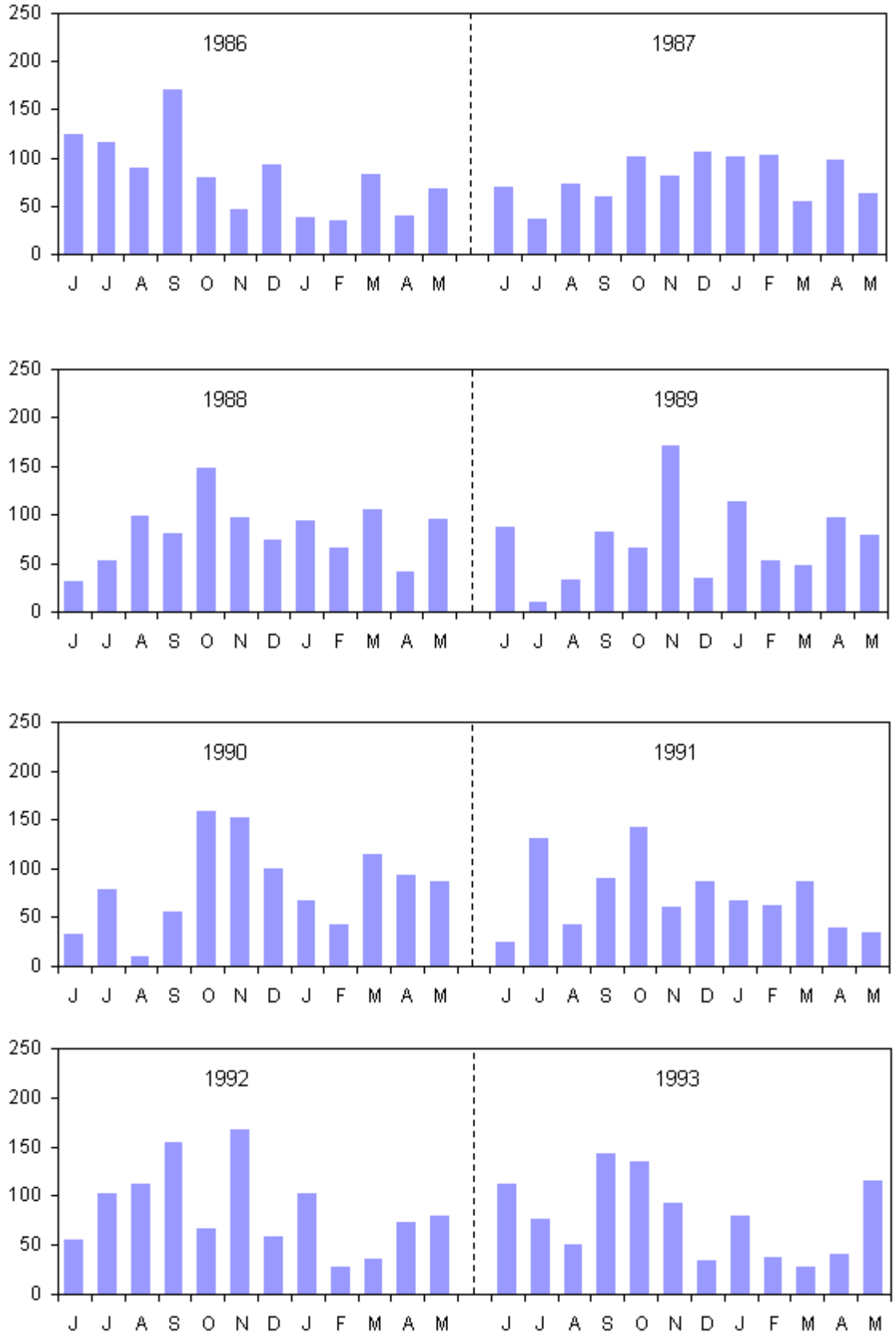


Figure 3 Muskoka/Haliburton Monthly Total Precipitation (mm/m)

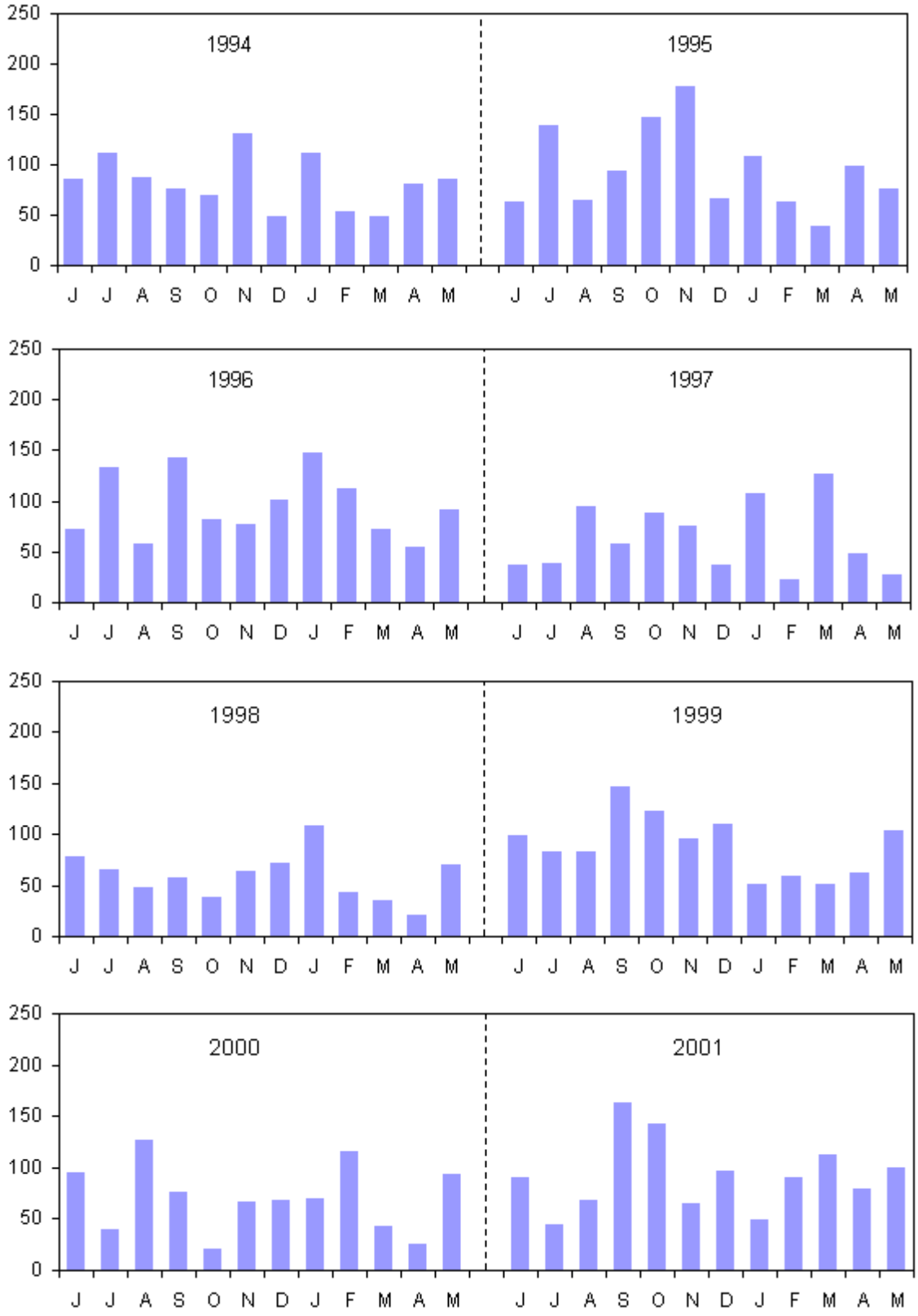


Figure 3 Muskoka/Haliburton Monthly Total Precipitation (mm/m)

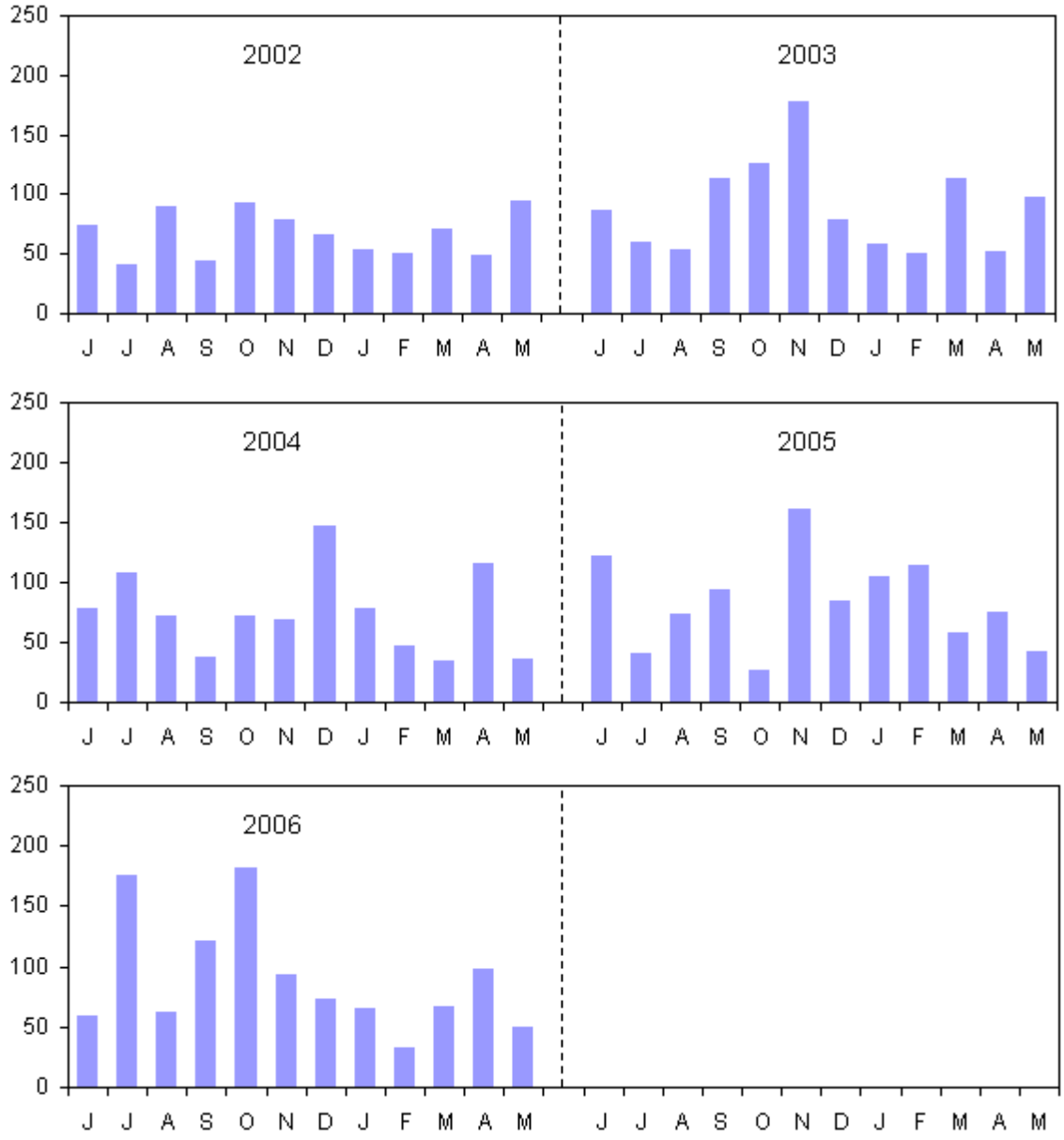
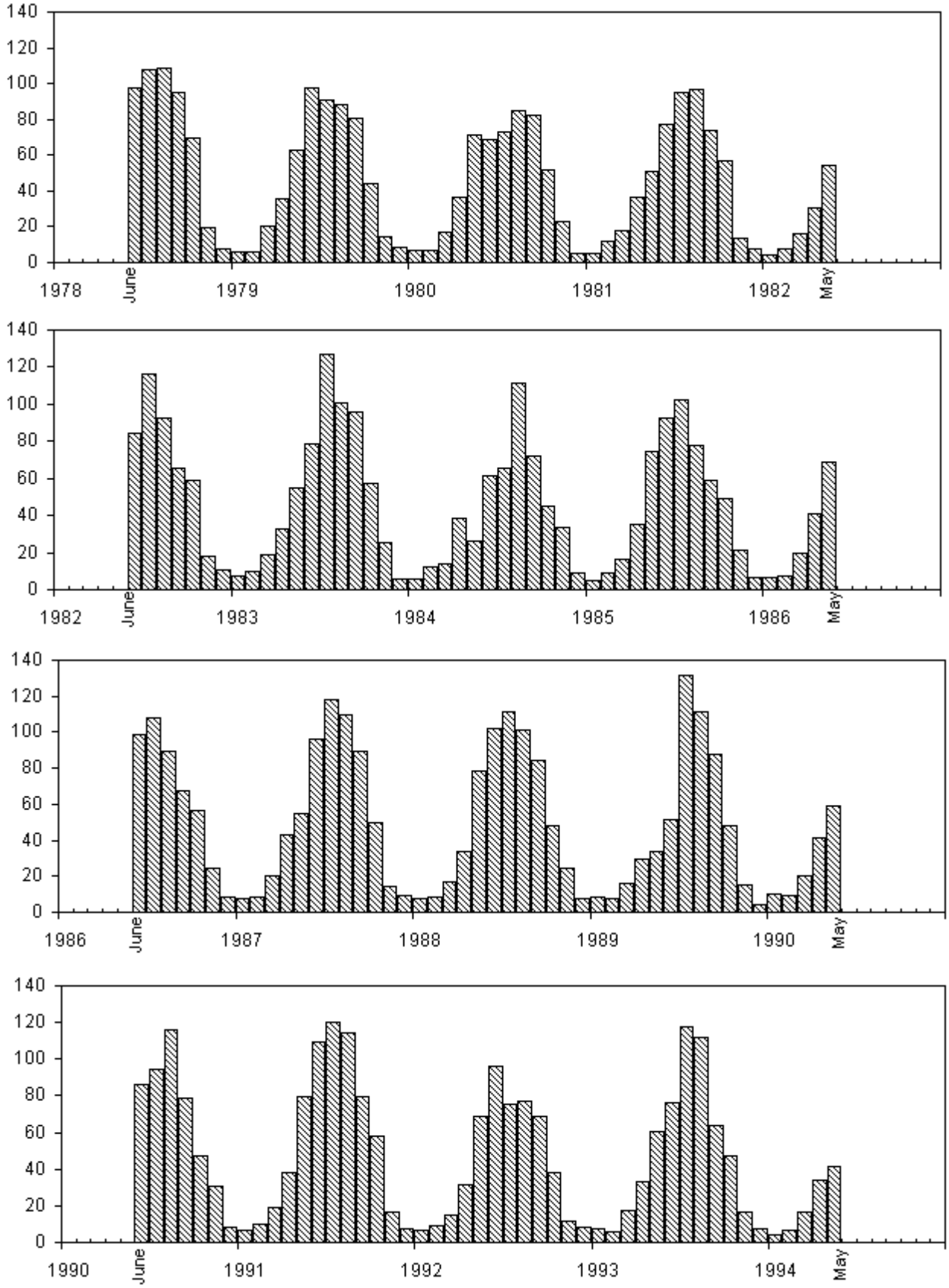


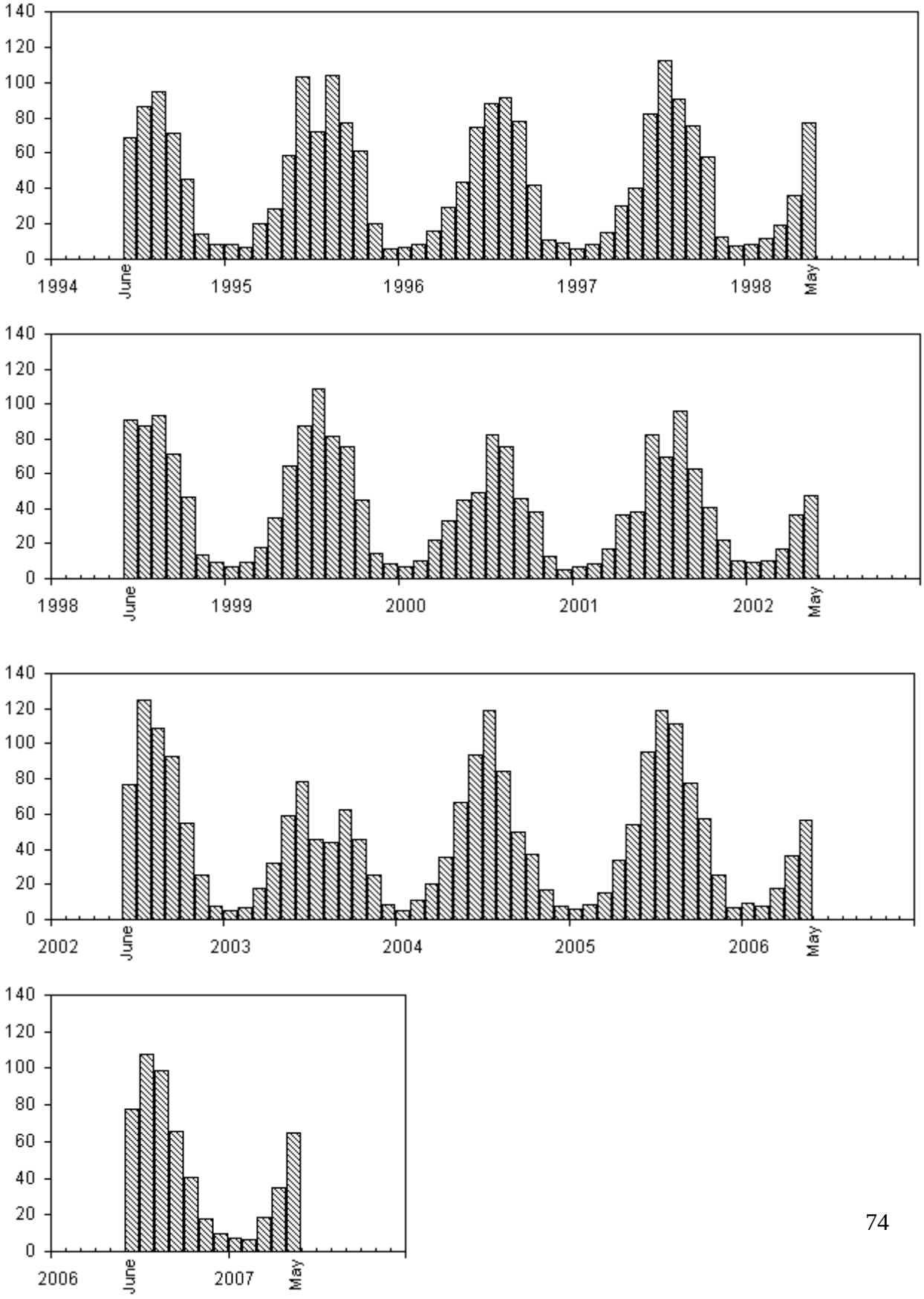
Figure 4 Monthly lake evaporation (mm/month) for eight lakes, 1978-2007

Blue Chalk
Chub
Crosson
Dickie
Harp
Heney
Plastic
Red Chalk

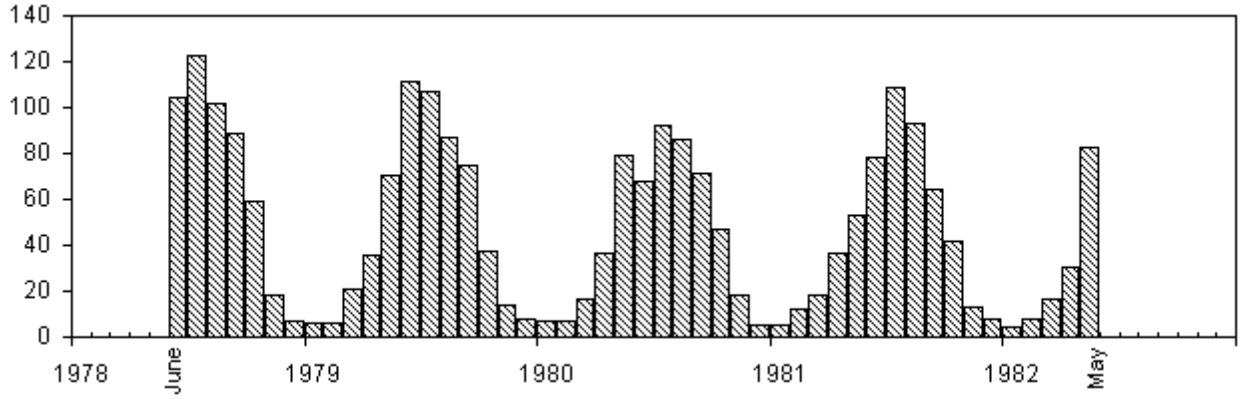
Blue Chalk Total Monthly Lake Evaporation (mm/m)

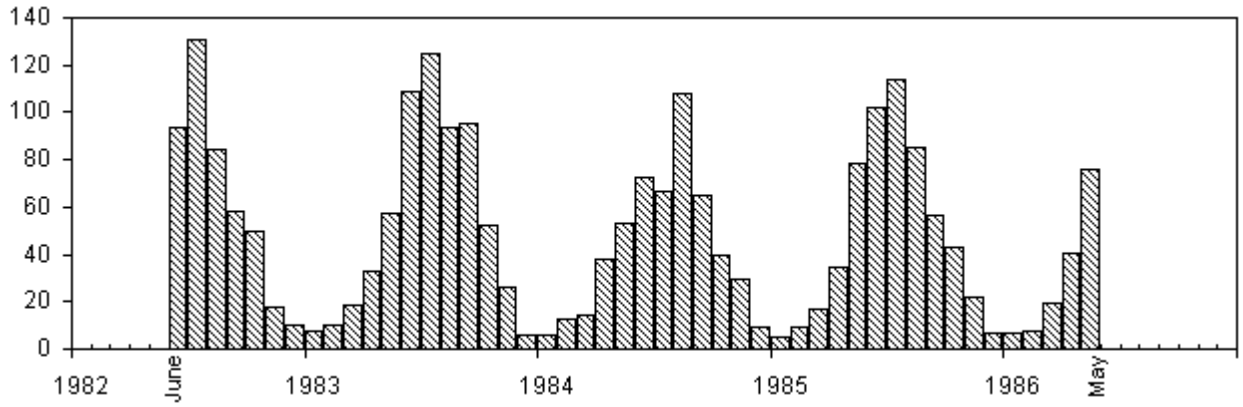


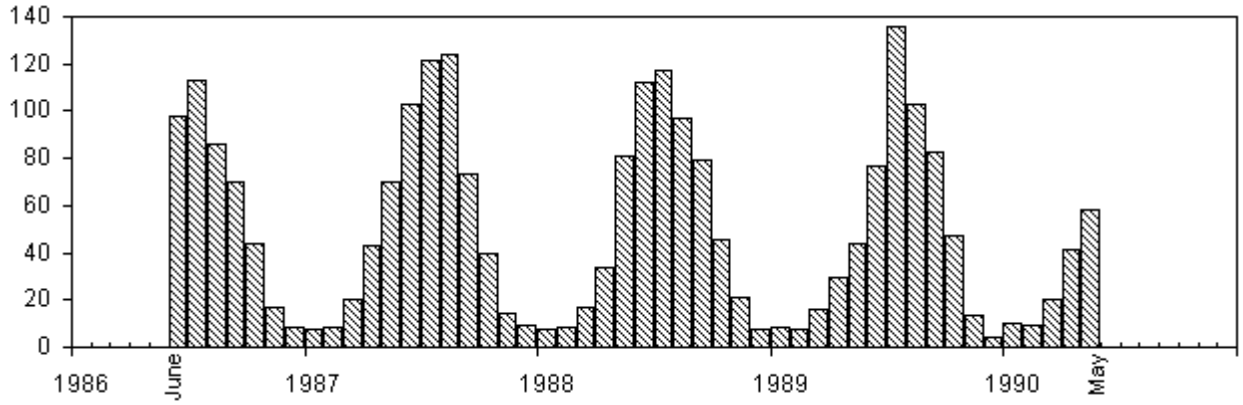
Blue Chalk Total Monthly Lake Evaporation (mm/m)

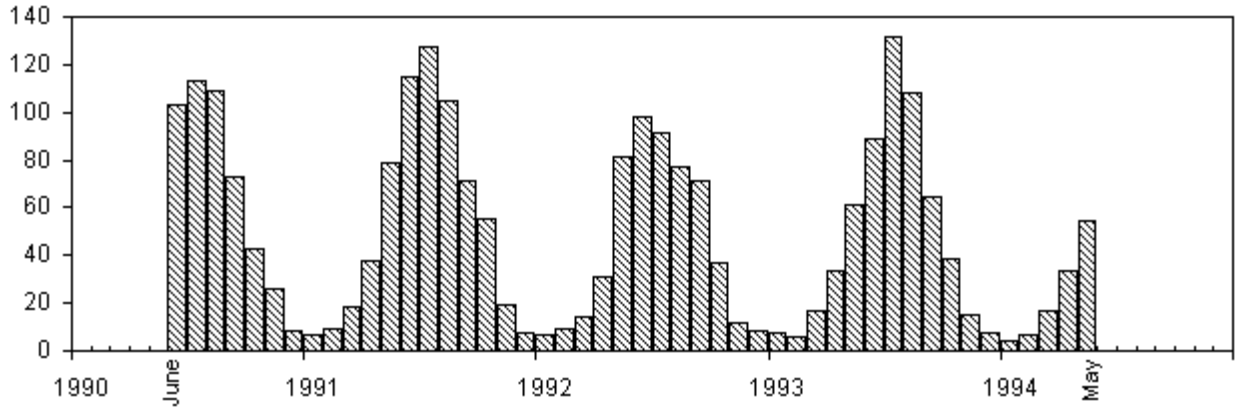


Chub Total Monthly Lake Evaporation (mm/m)

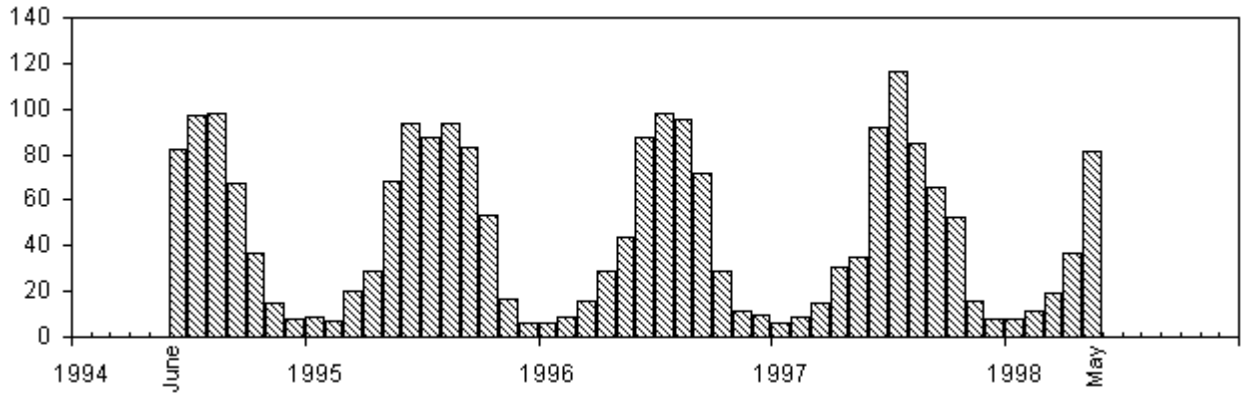


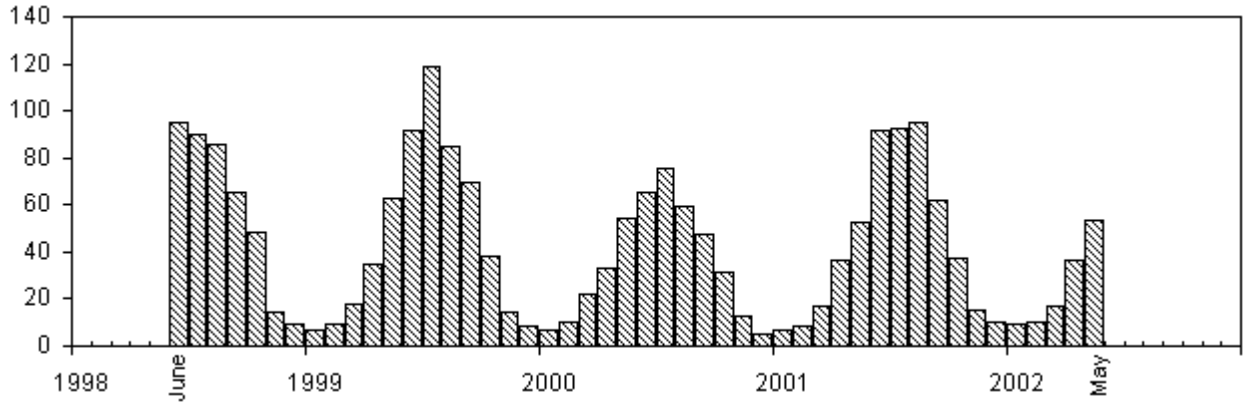


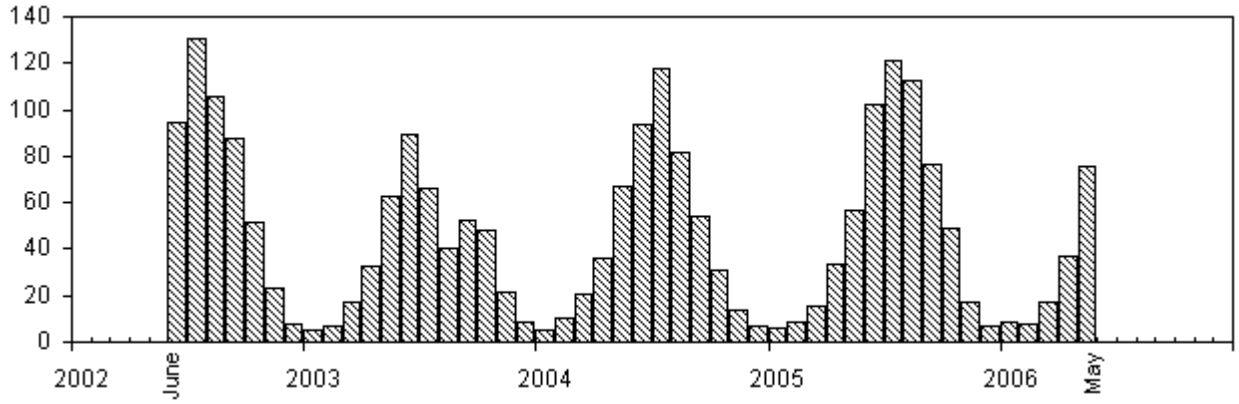


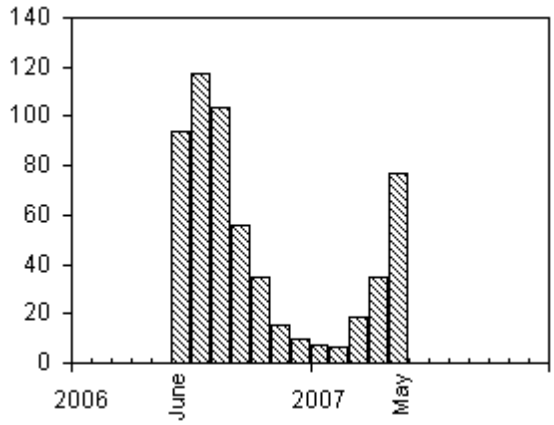


Chub Total Monthly Lake Evaporation (mm/m)

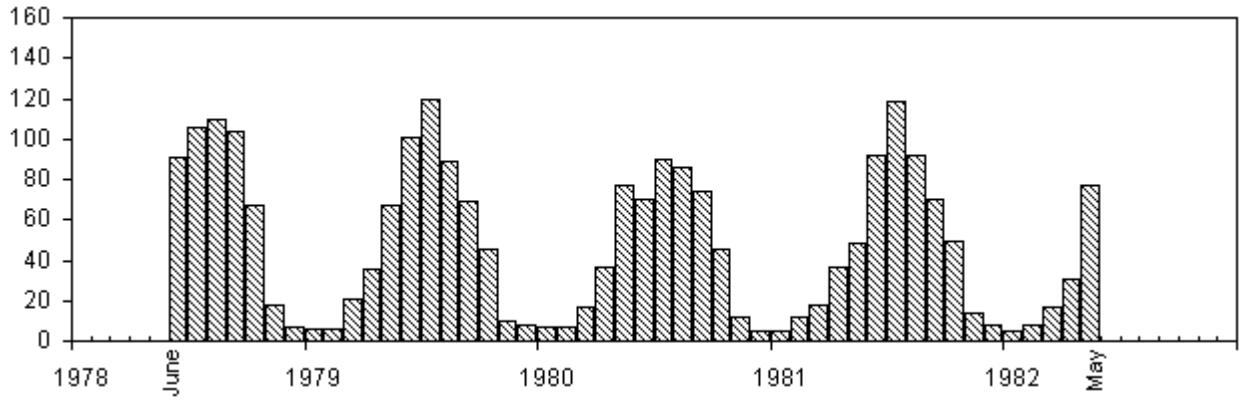


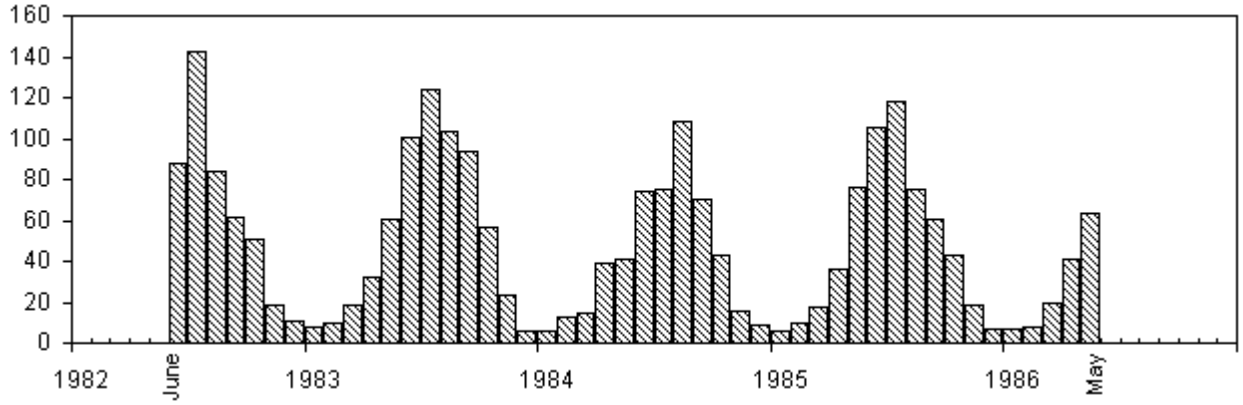


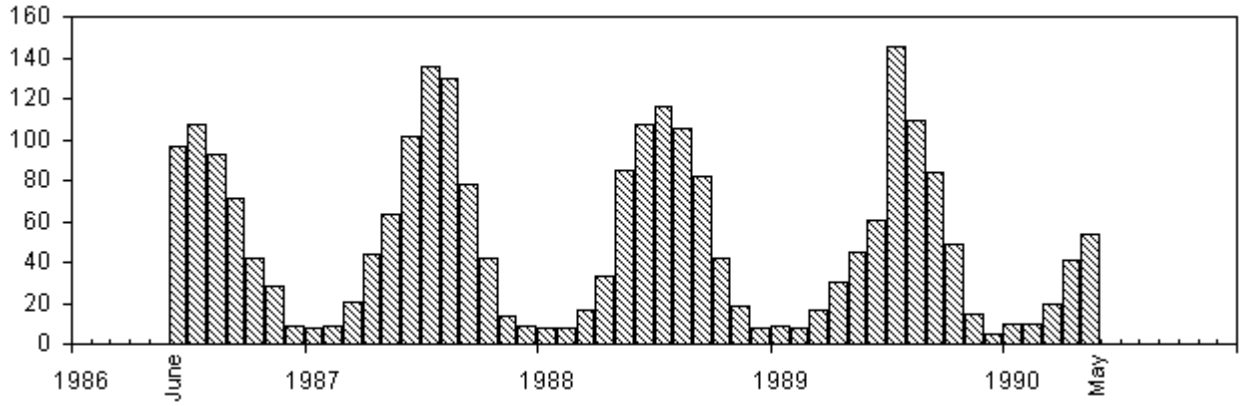


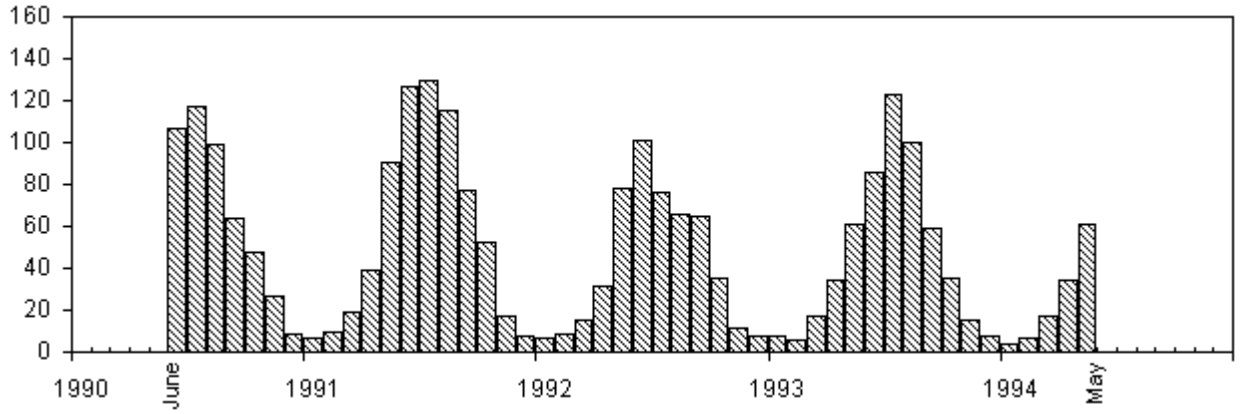


Crosson Total Monthly Lake Evaporation (mm/m)

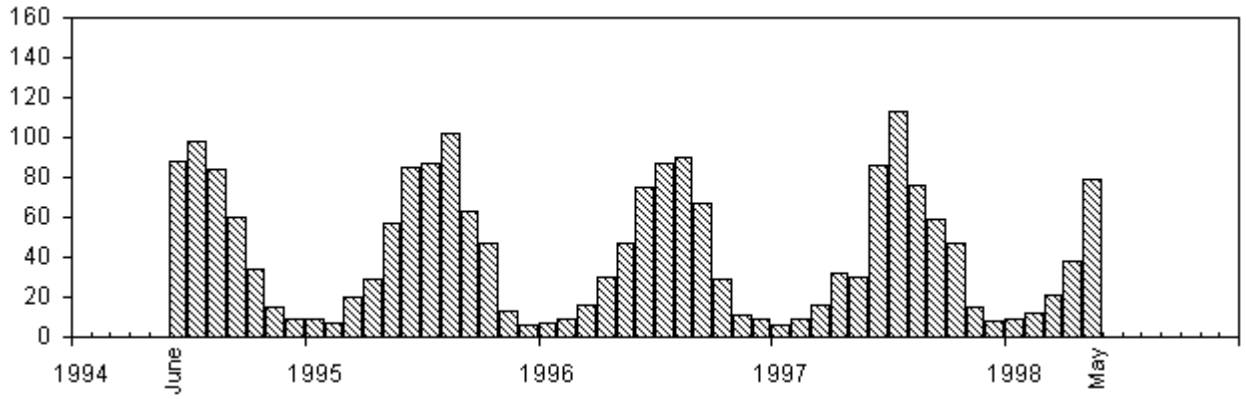


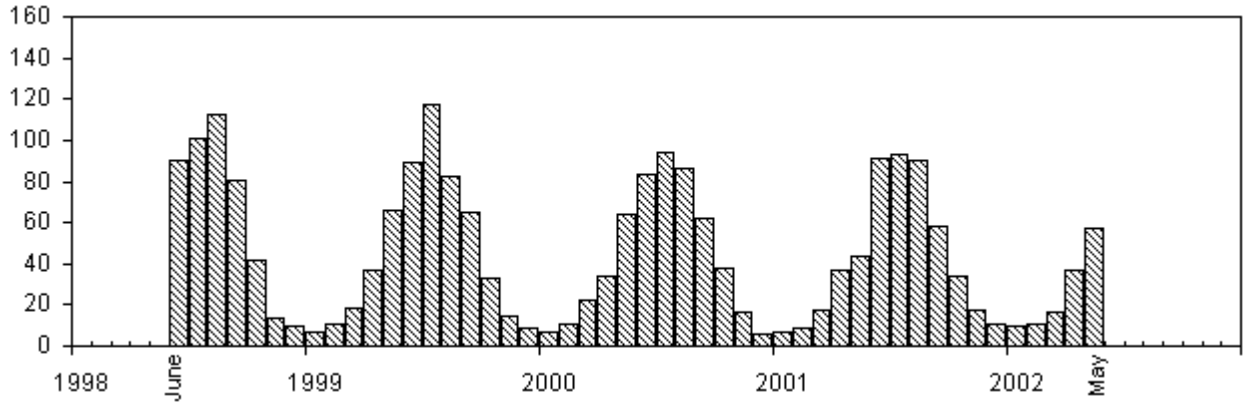


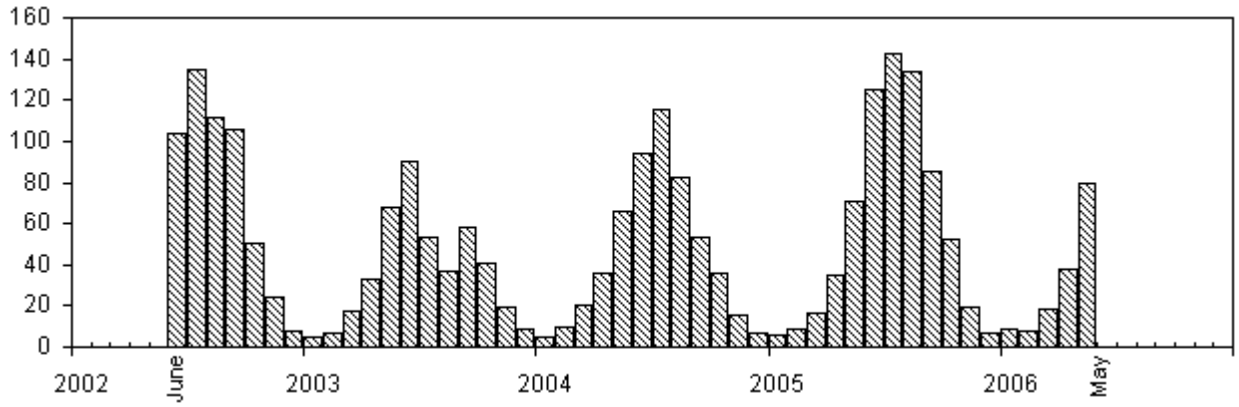


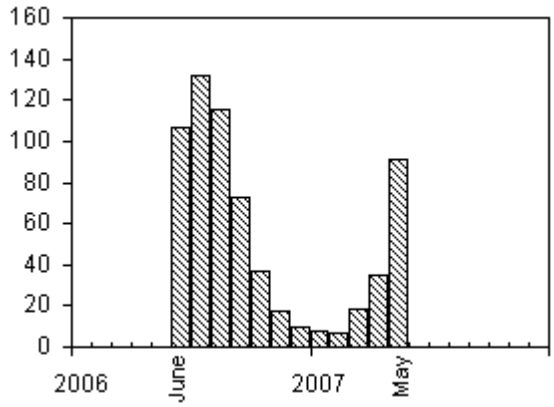


Crosson Total Monthly Lake Evaporation (mm/m)

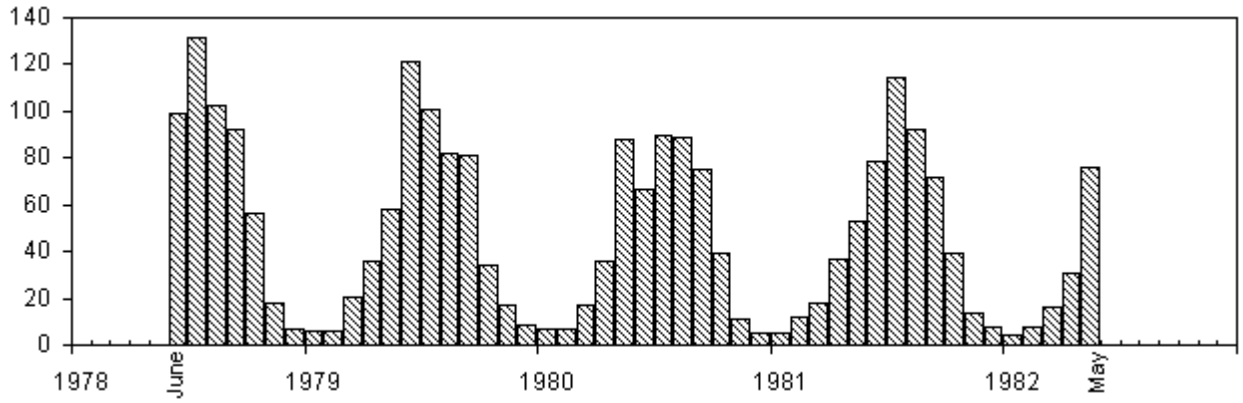


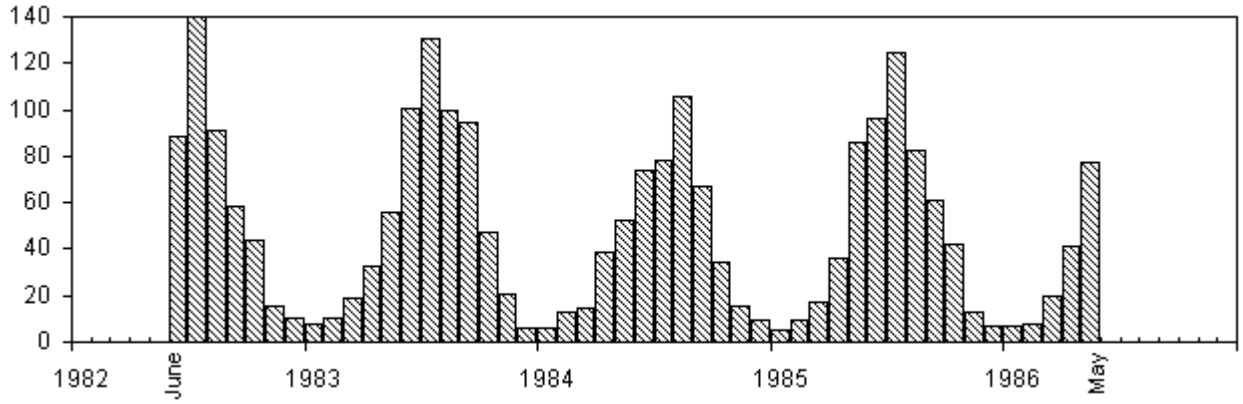


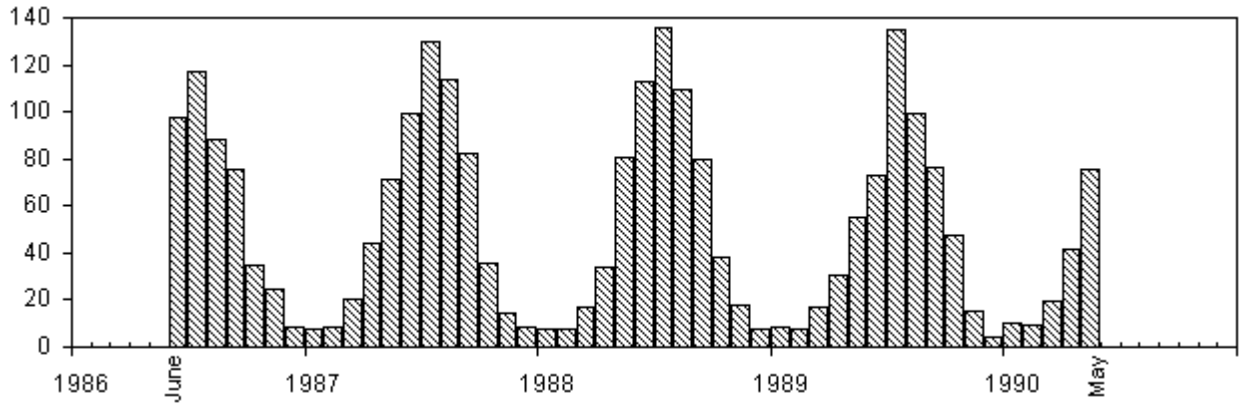


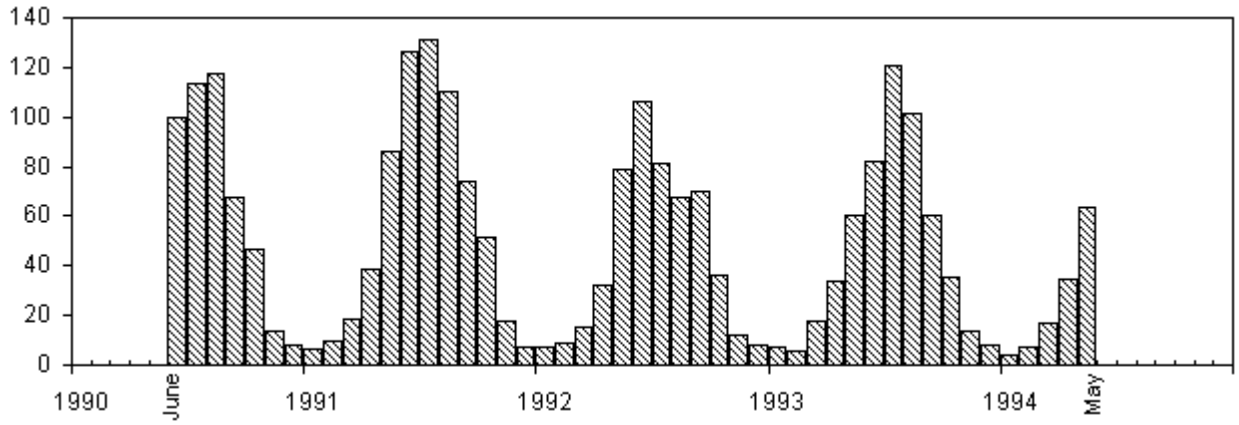


Dickie Total Monthly Lake Evaporation (mm/m)

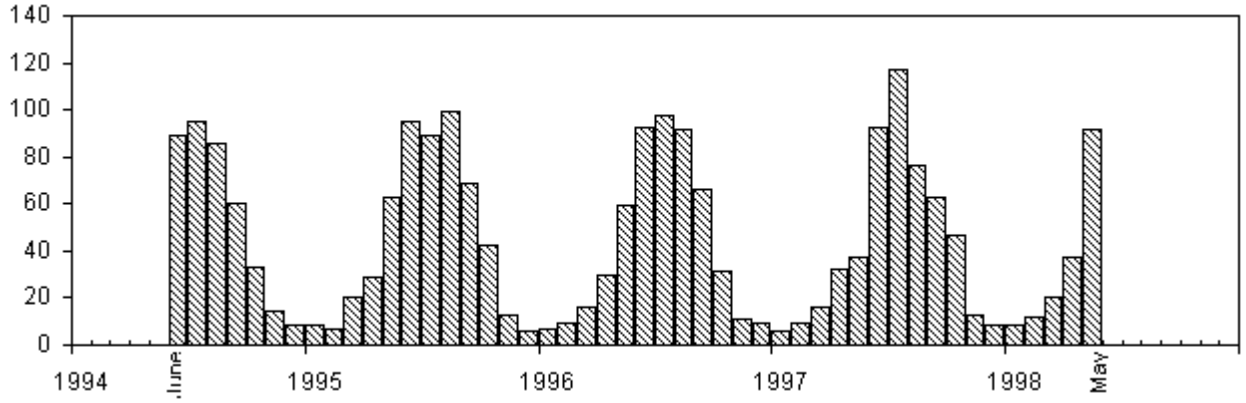


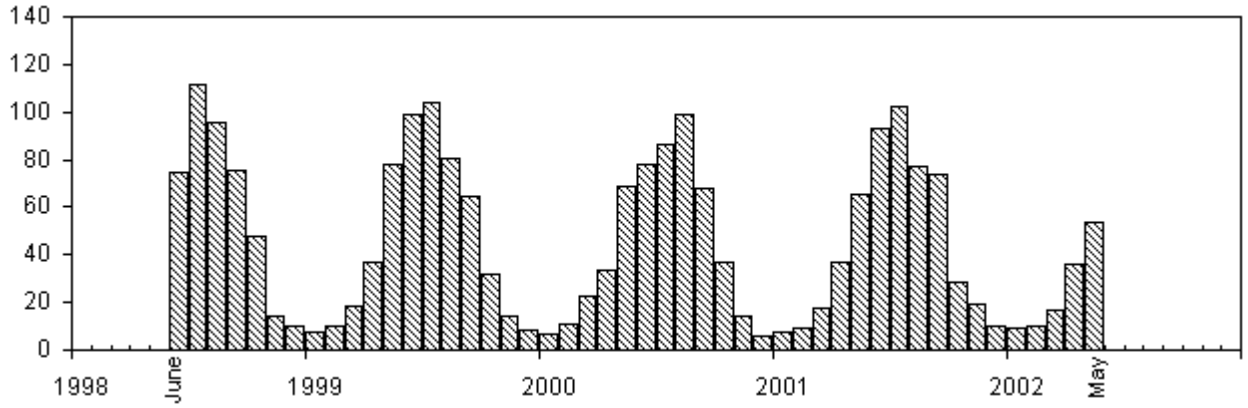


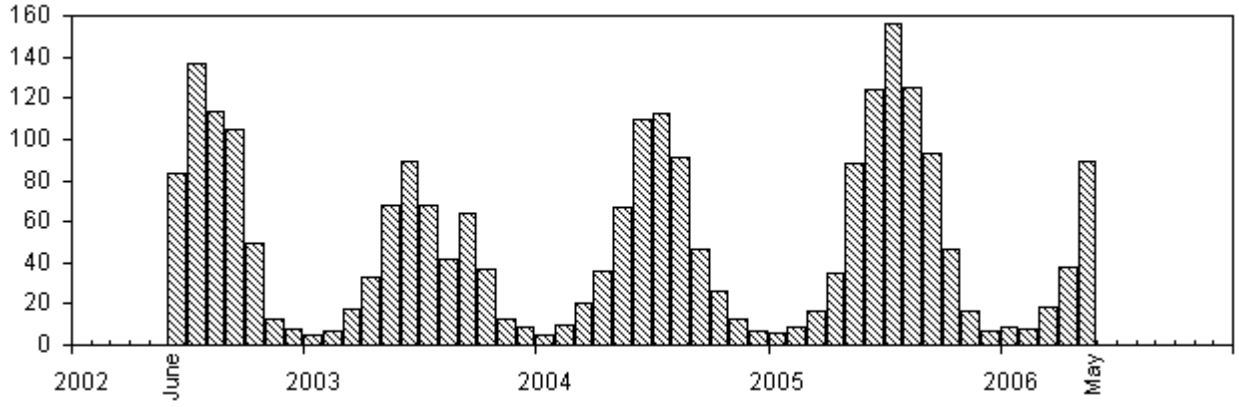


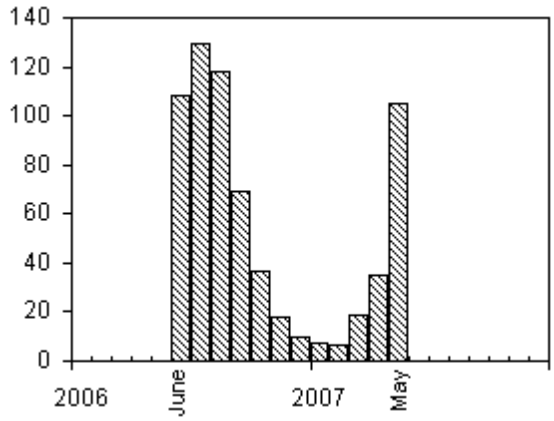


Dickie Total Monthly Lake Evaporation (mm/m)

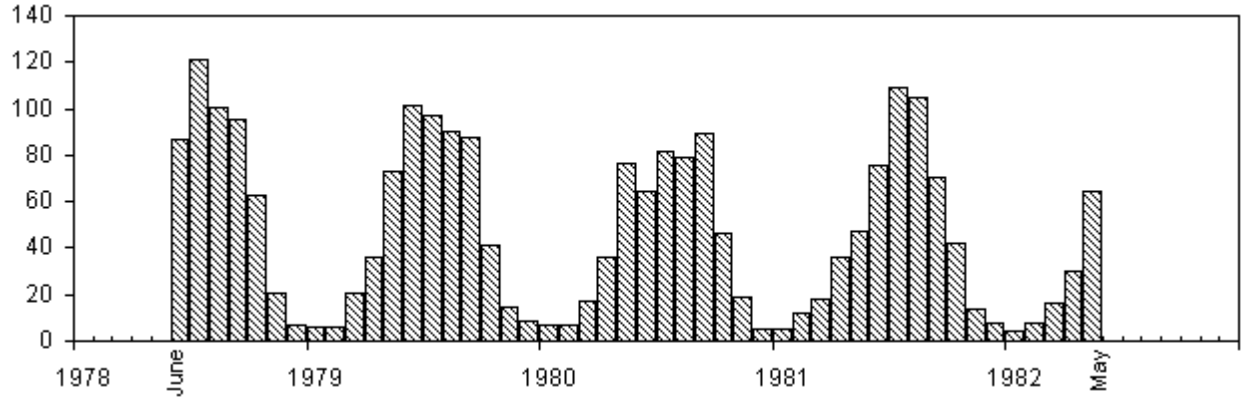


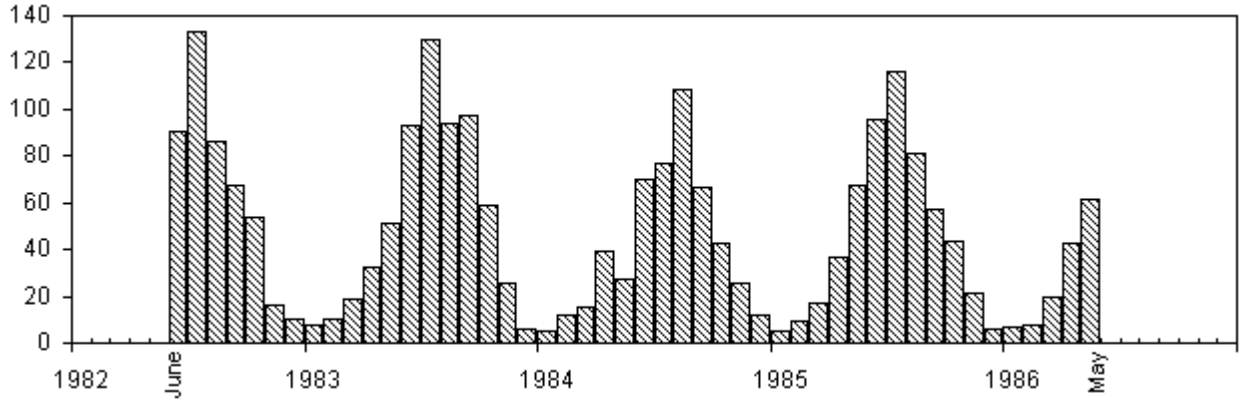


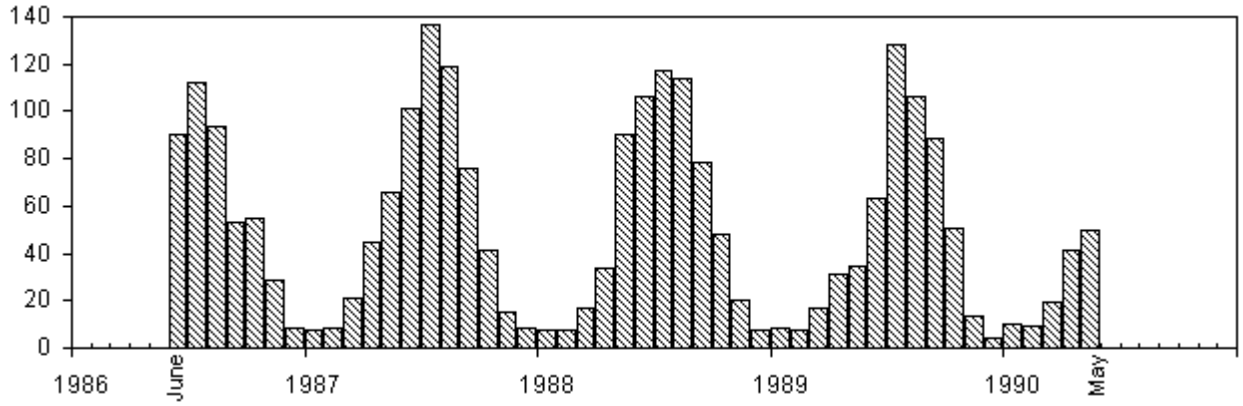


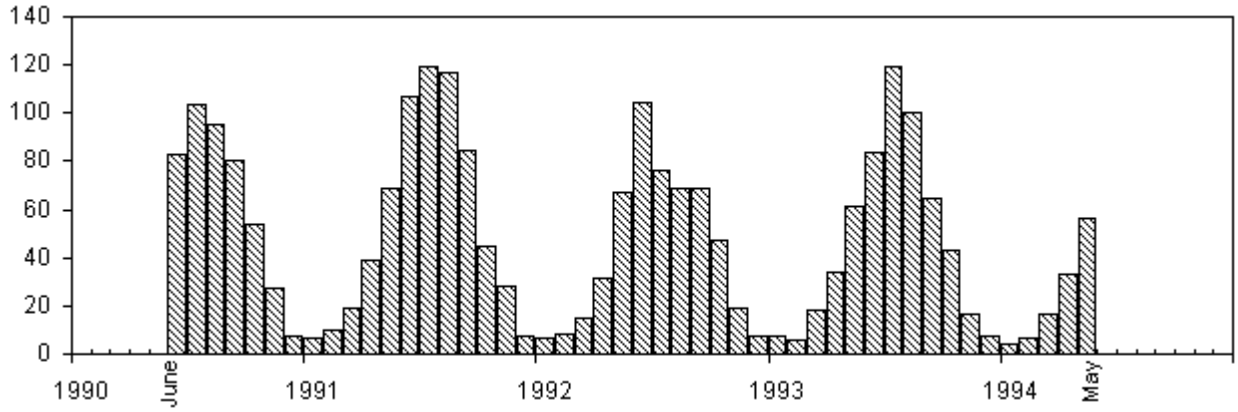


Harp Total Monthly Lake Evaporation (mm/m)

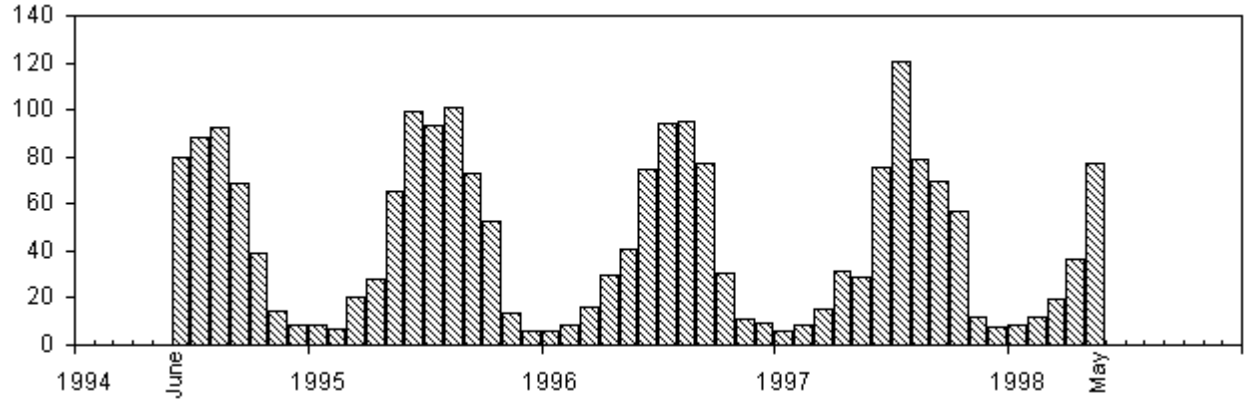


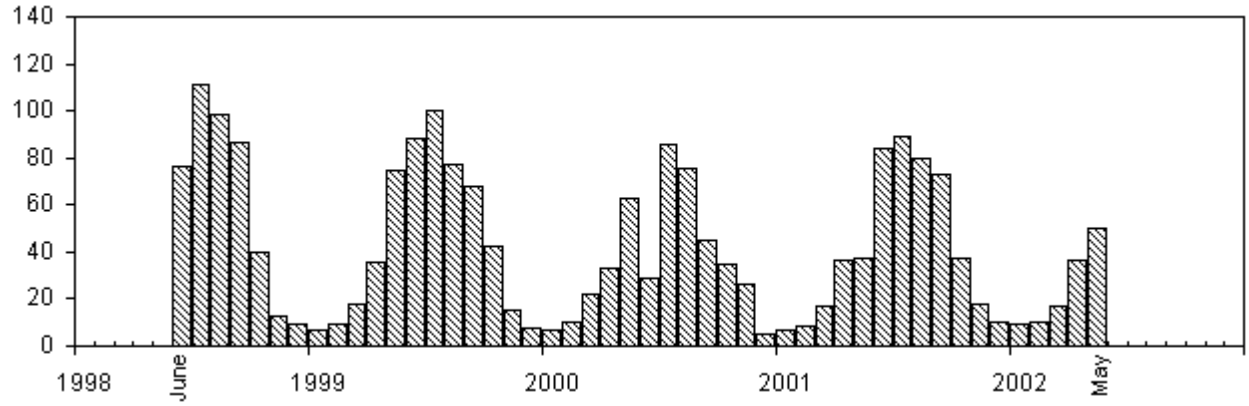


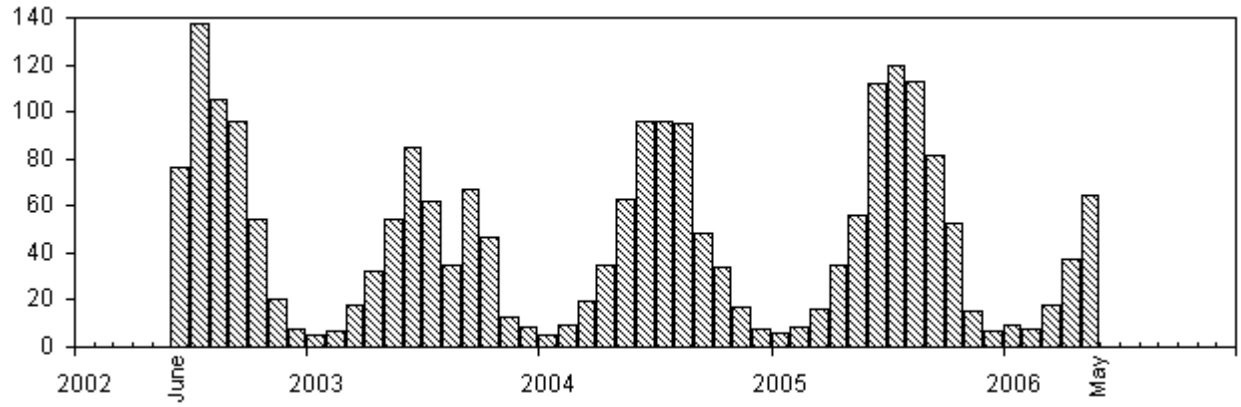


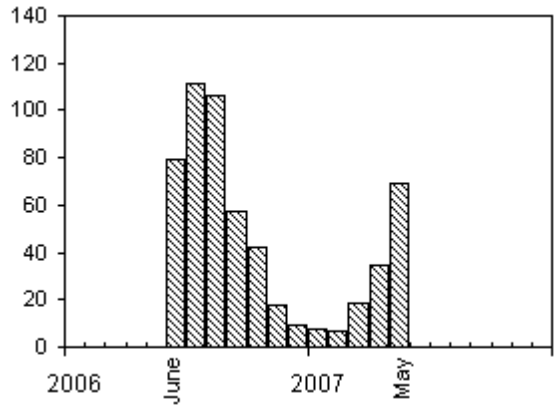


Harp Total Monthly Lake Evaporation (mm/m)

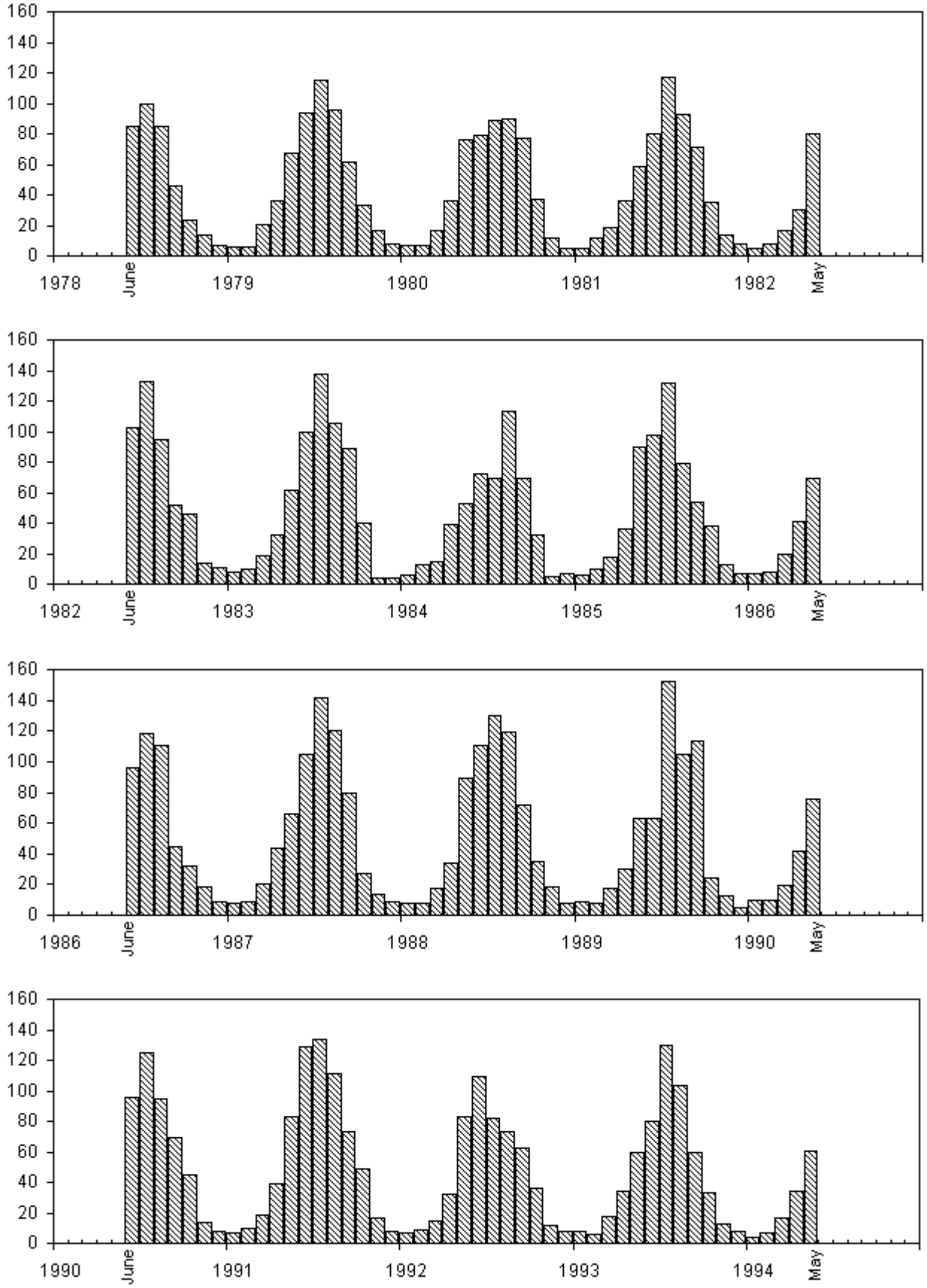




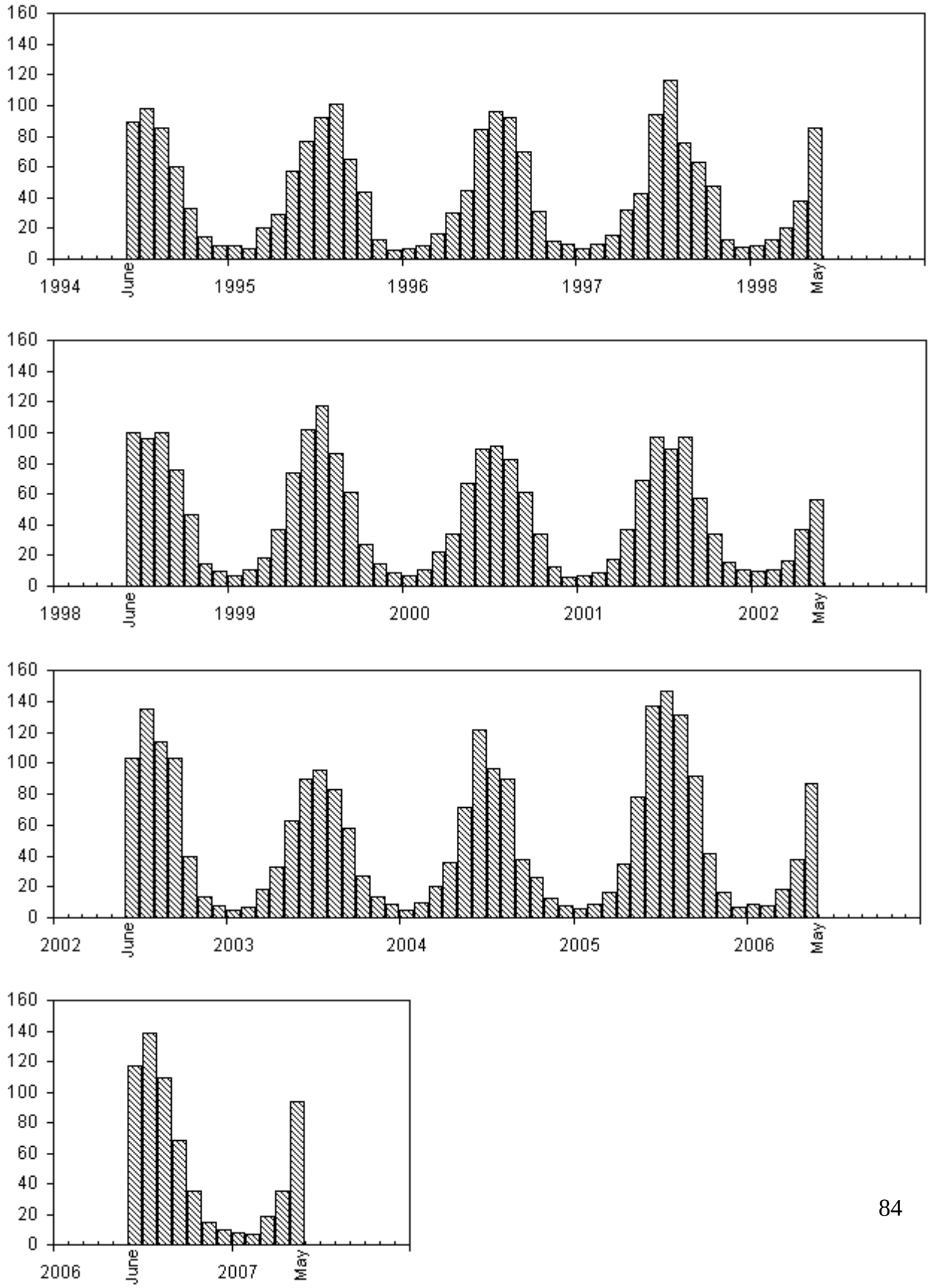




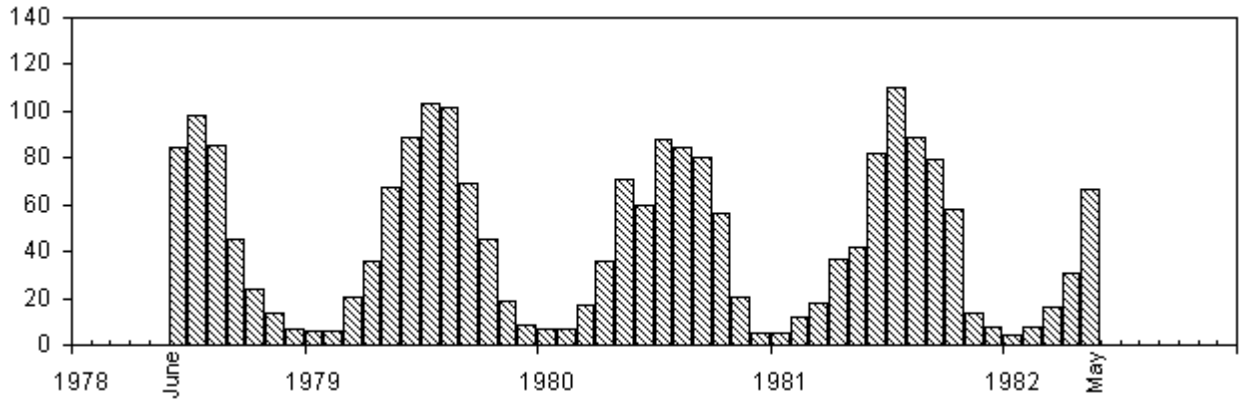
Heney Total Monthly Lake Evaporation (mm/m)

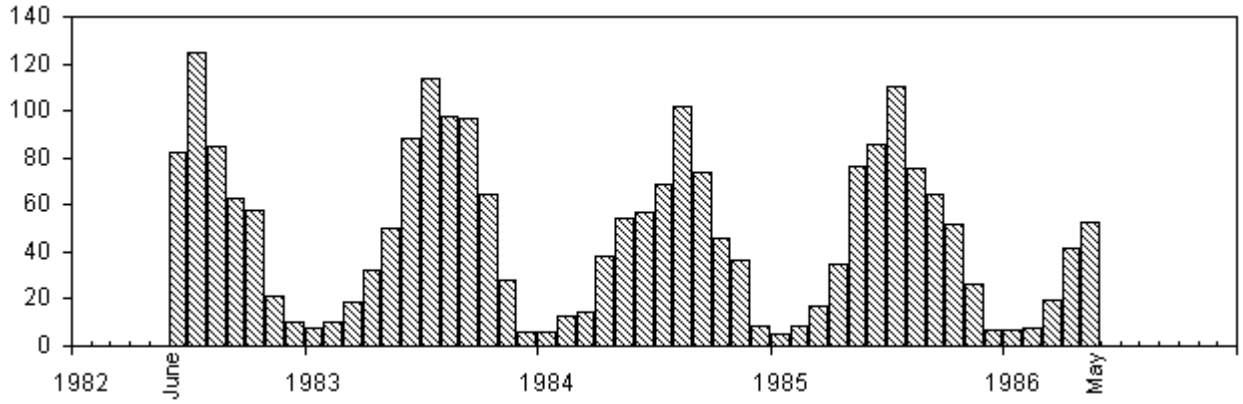


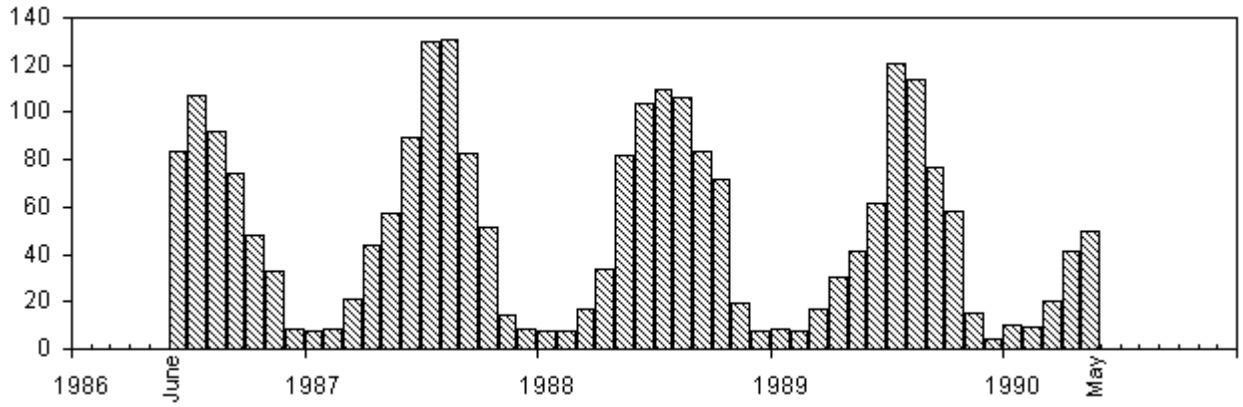
Heney Total Monthly Lake Evaporation (mm/m)

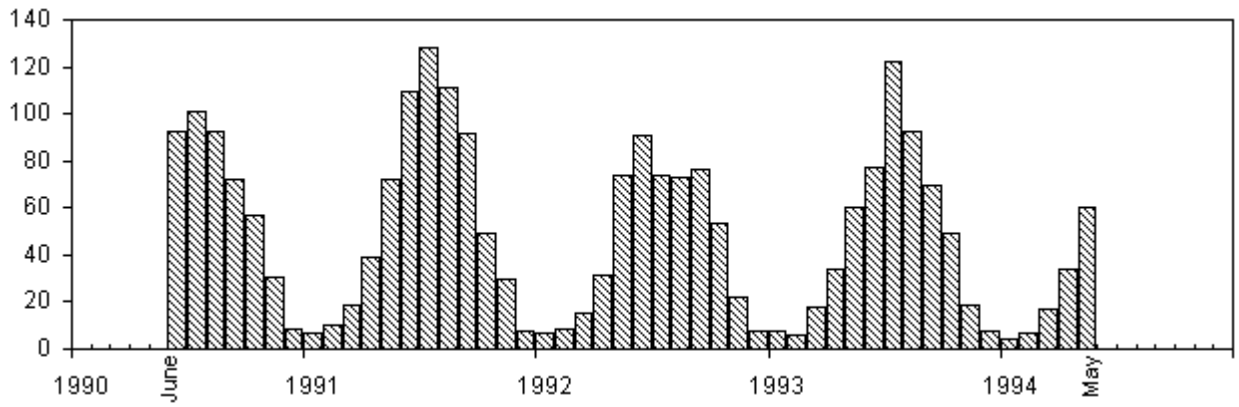


Plastic Total Monthly Lake Evaporation (mm/m)

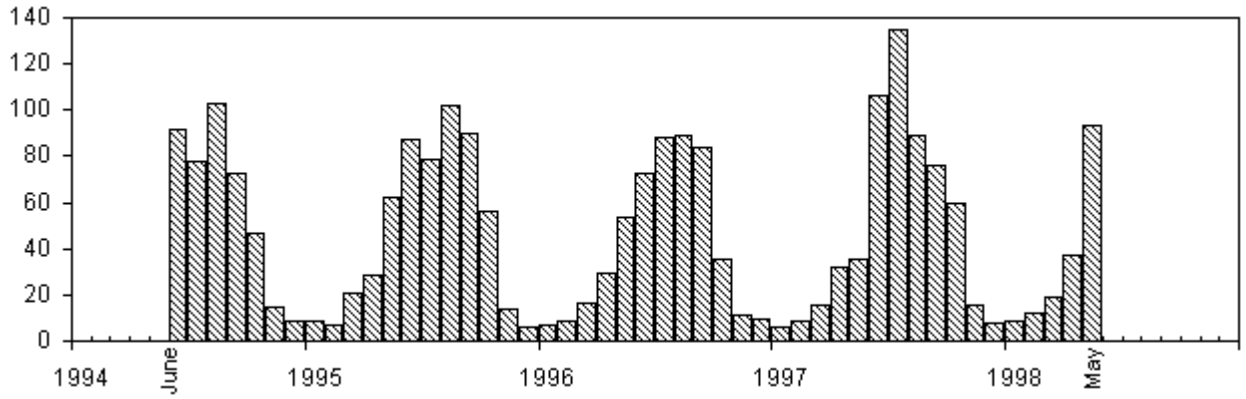


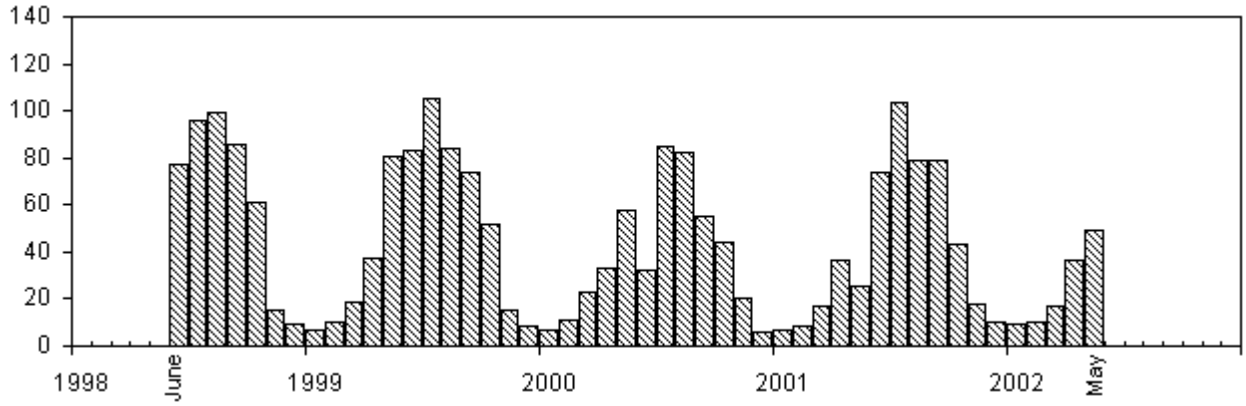


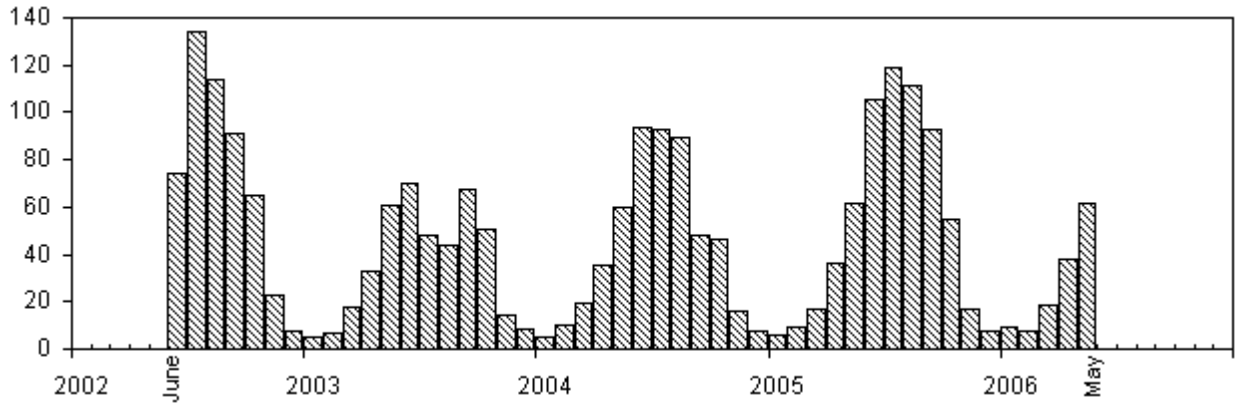


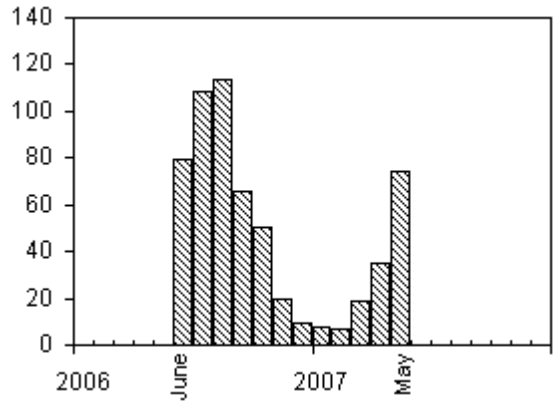


Plastic Total Monthly Lake Evaporation (mm/m)

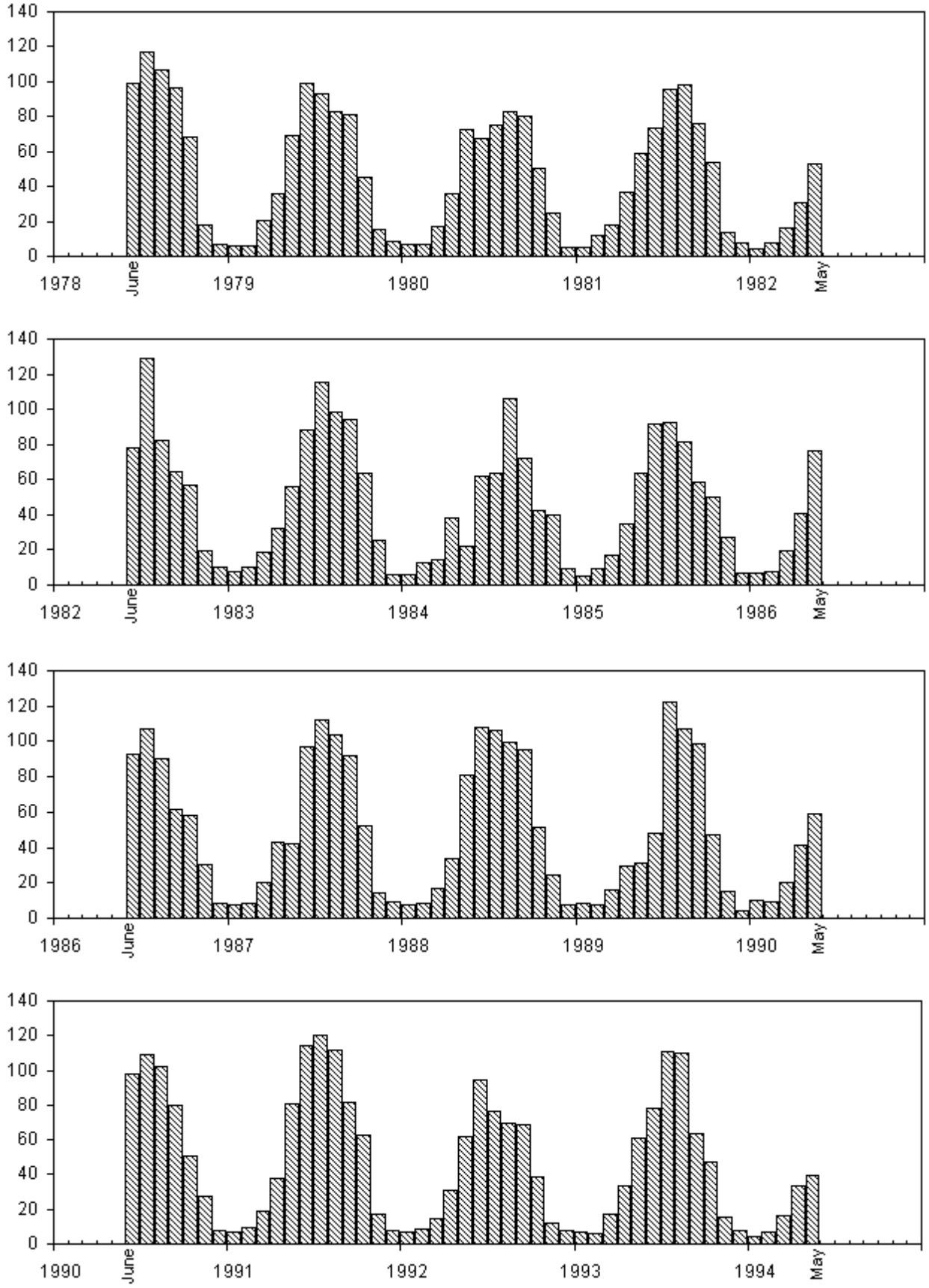




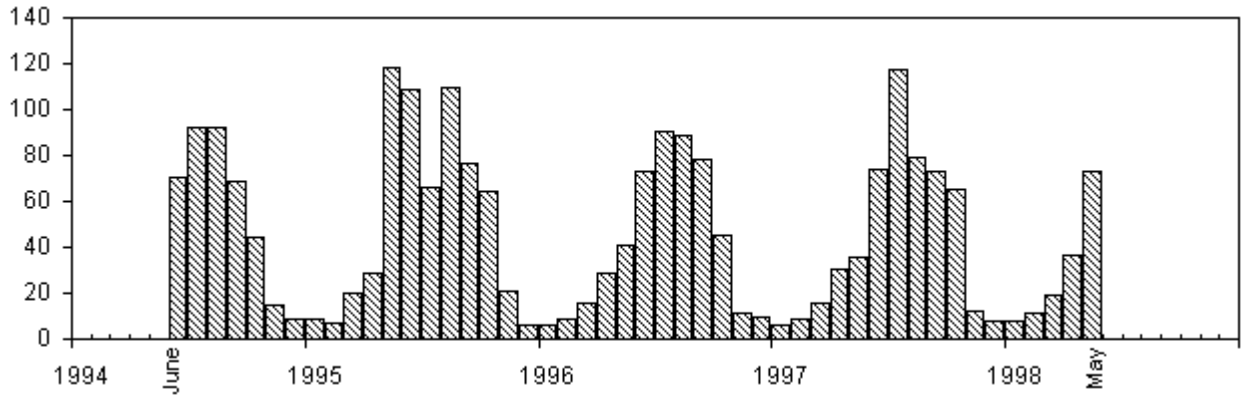


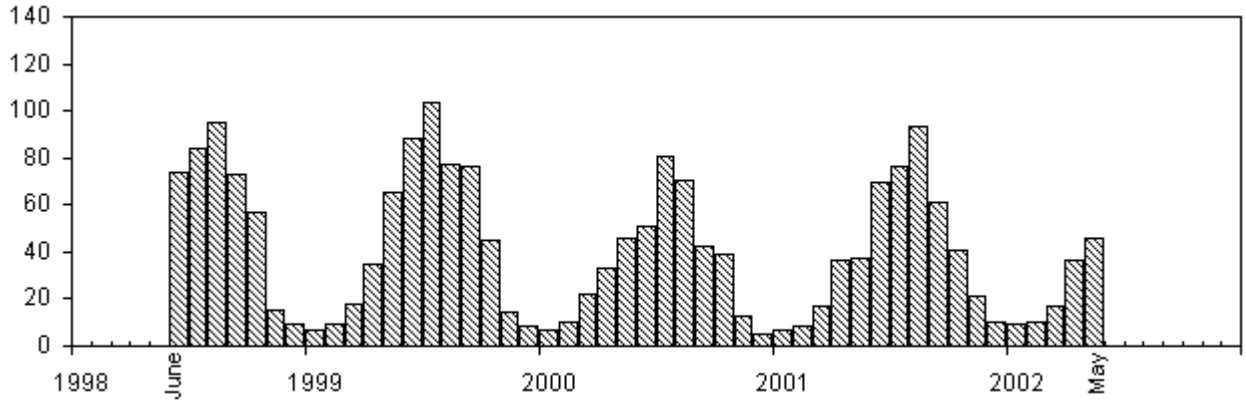


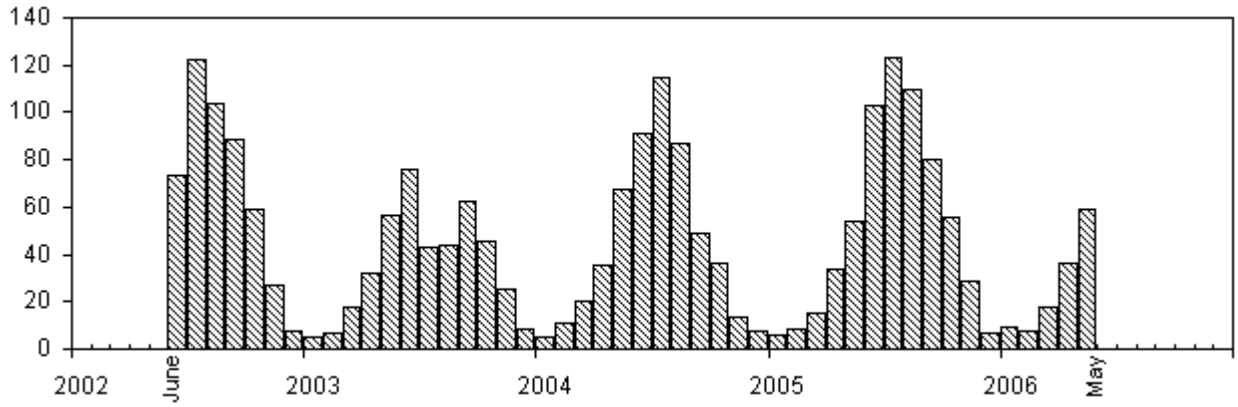
Red Chalk Total Monthly Lake Evaporation (mm/m)



Red Chalk Total Monthly Lake Evaporation (mm/m)







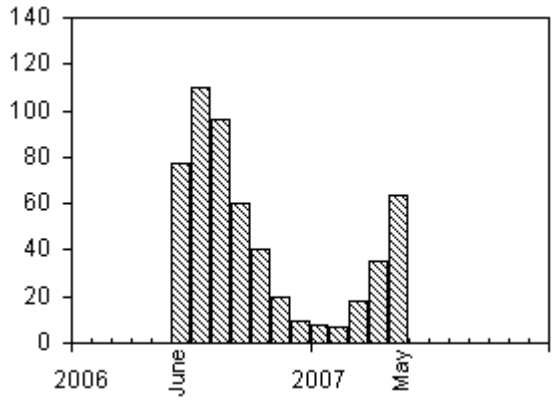
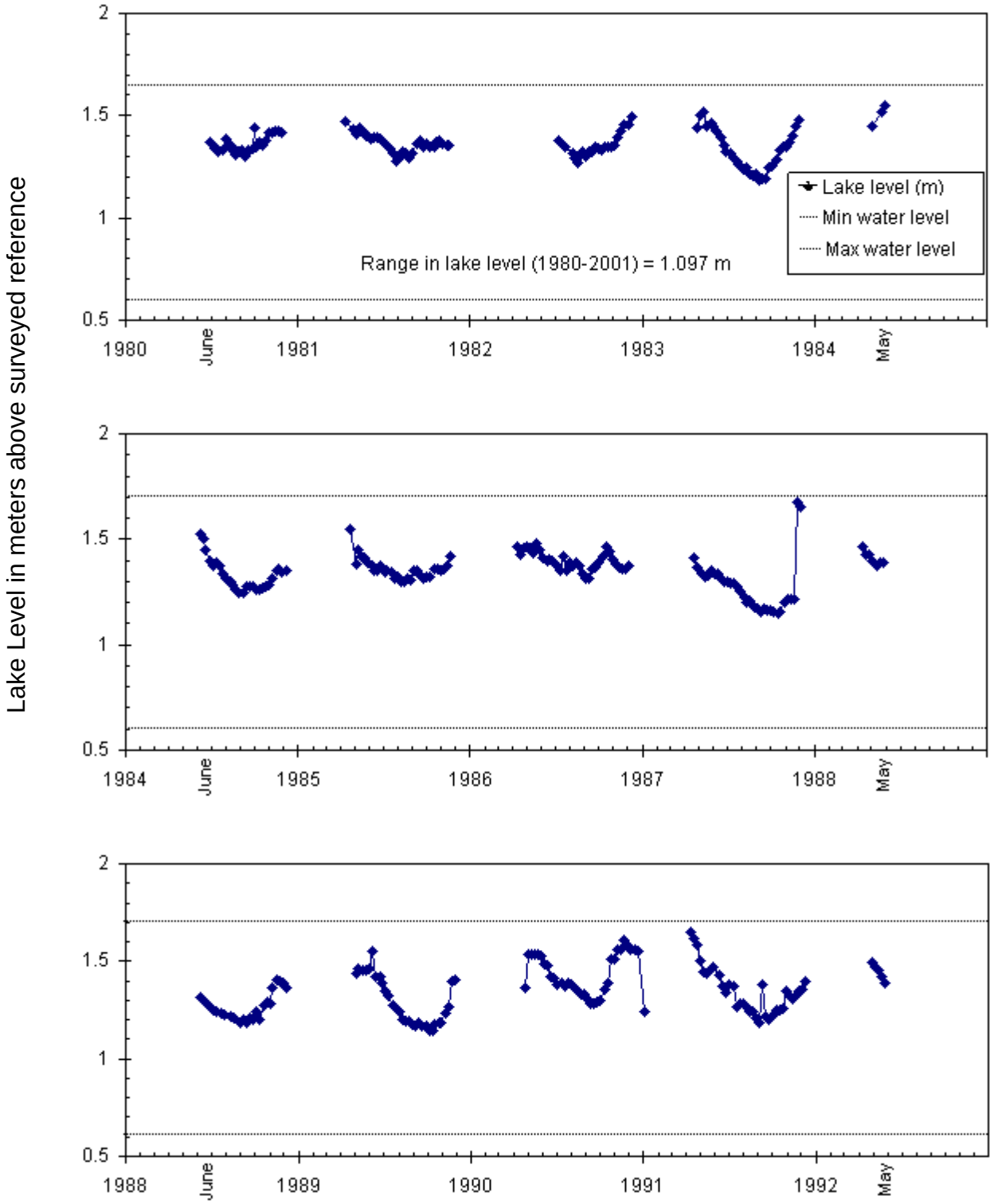


Figure 5 Lake level gauge (m) for eight lakes, 1980-2002

Blue Chalk
Chub
Crosson
Dickie
Harp
Heney
Plastic
Red Chalk

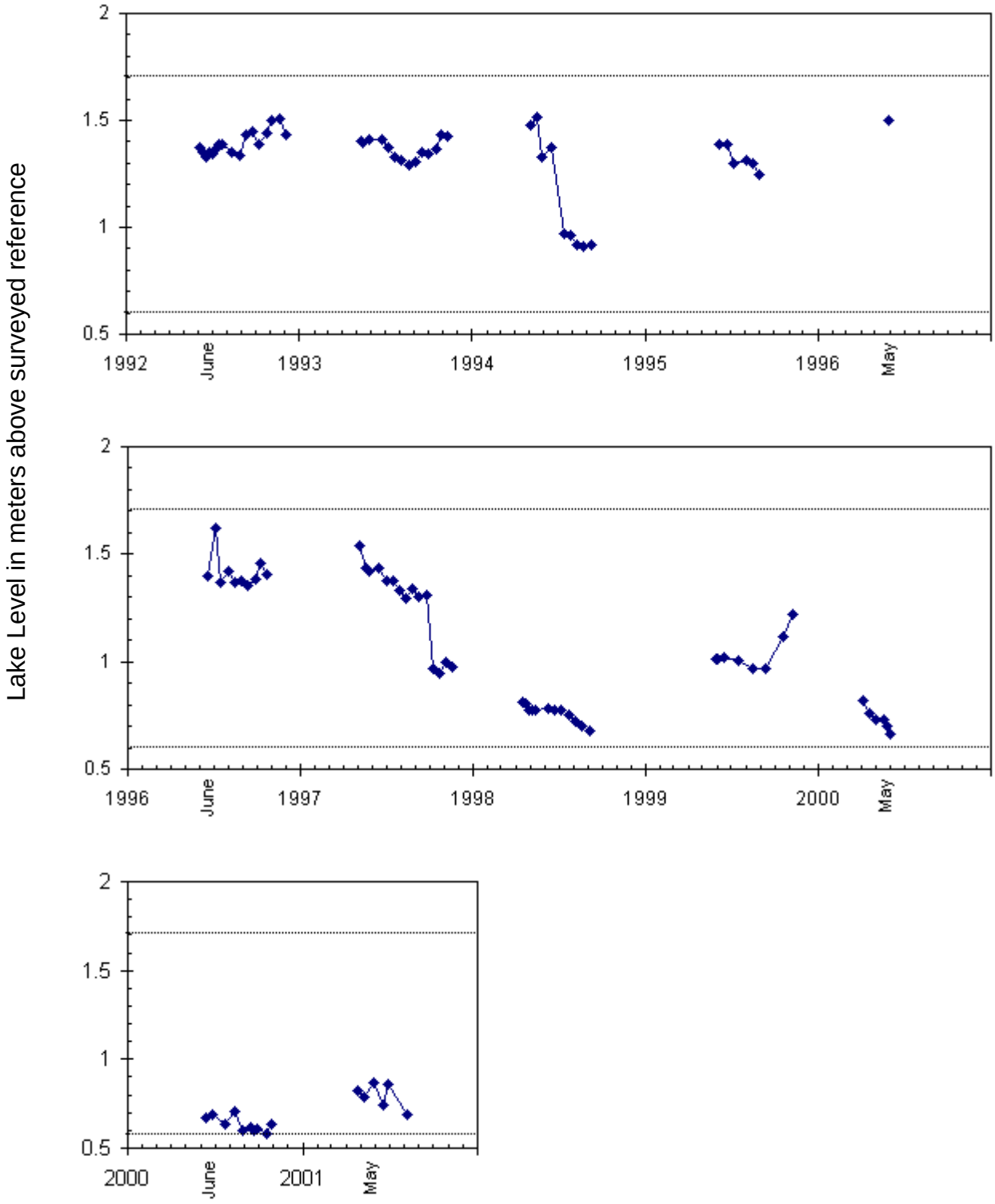
Blue Chalk Lake Level

Lake Elevation 343.5 m ASL



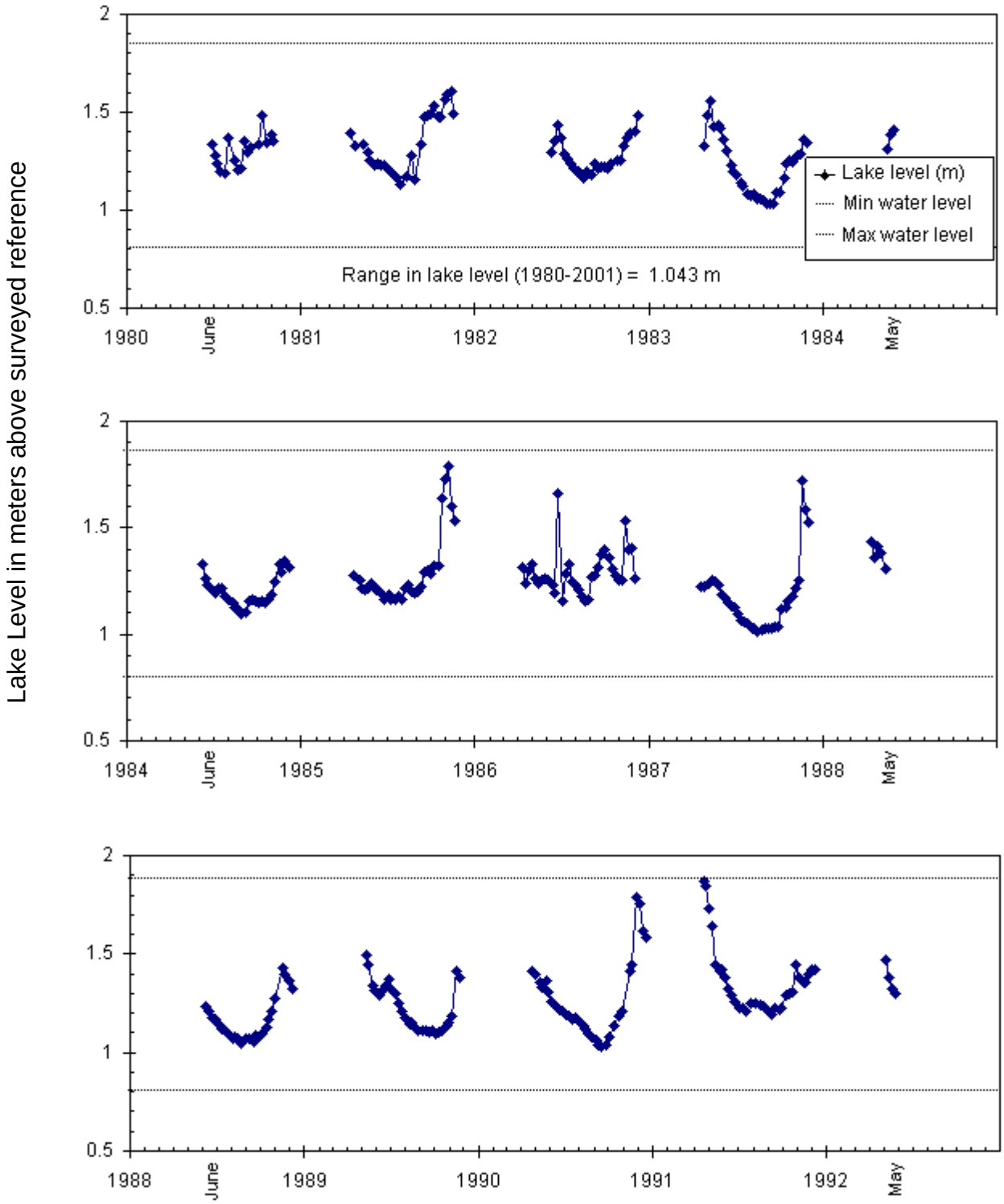
Blue Chalk Lake Level

Lake Elevation 343.5 m ASL



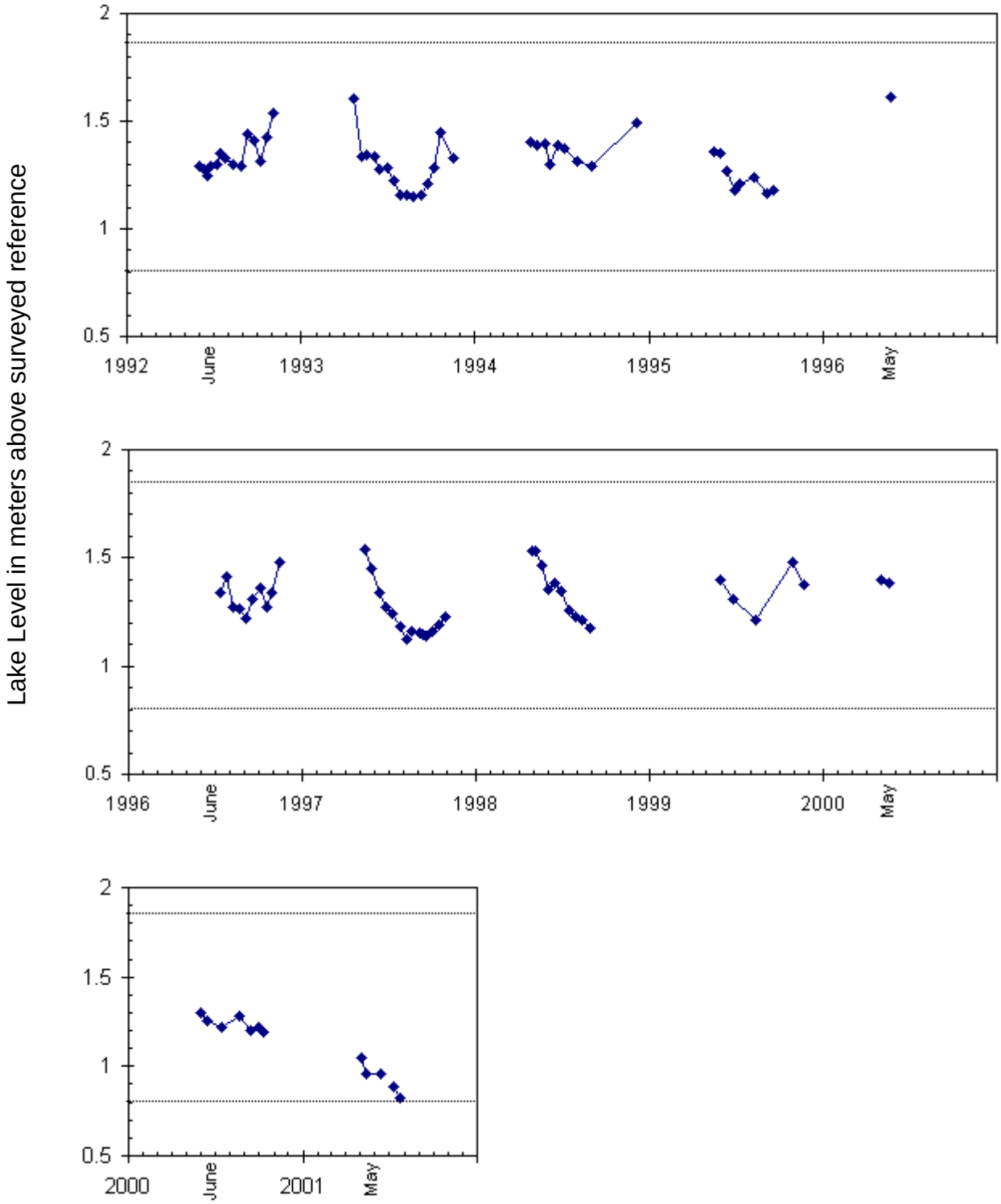
Chub Lake Level

Lake Elevation 371 m ASL



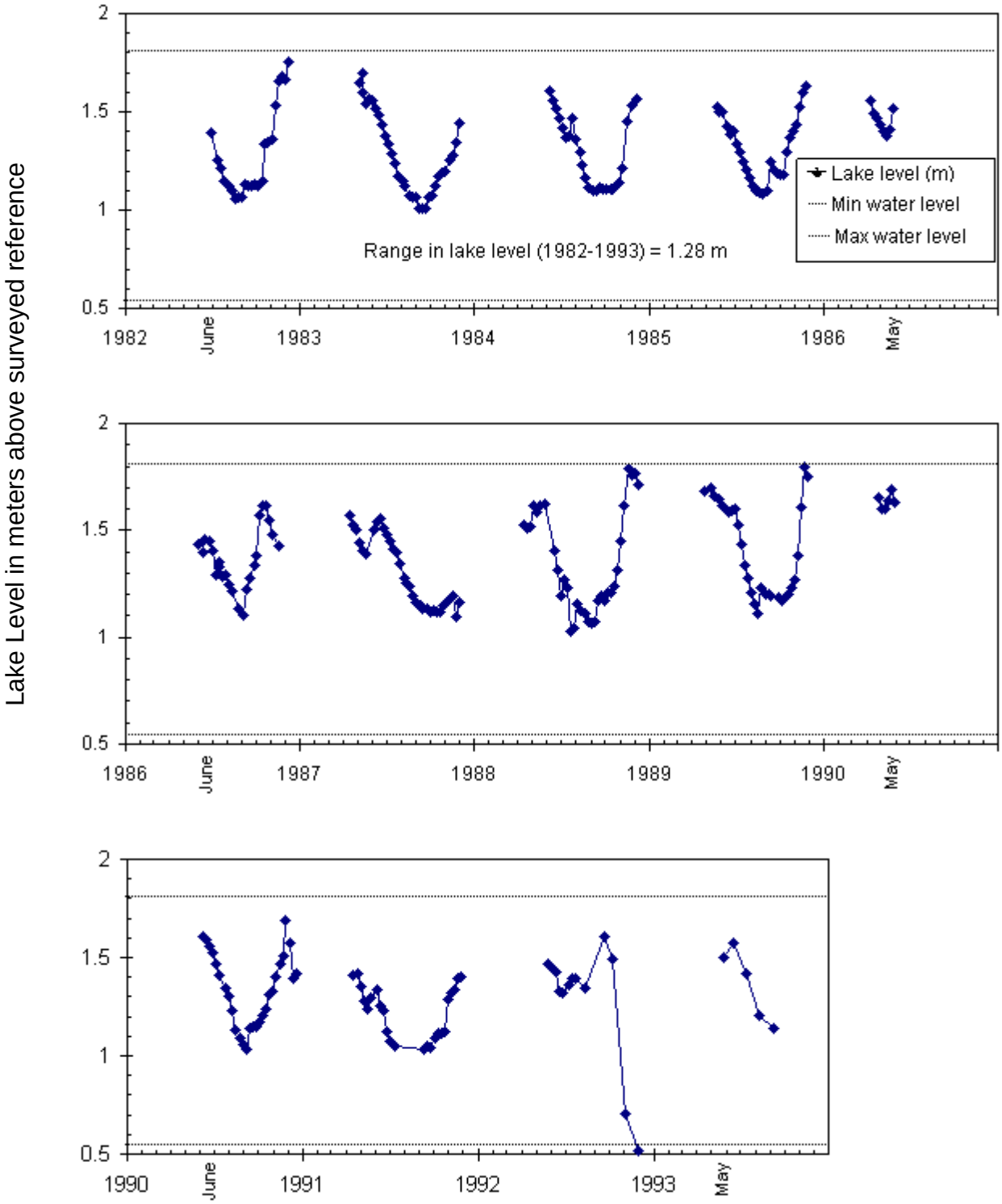
Chub Lake Level

Lake Elevation 371 m ASL



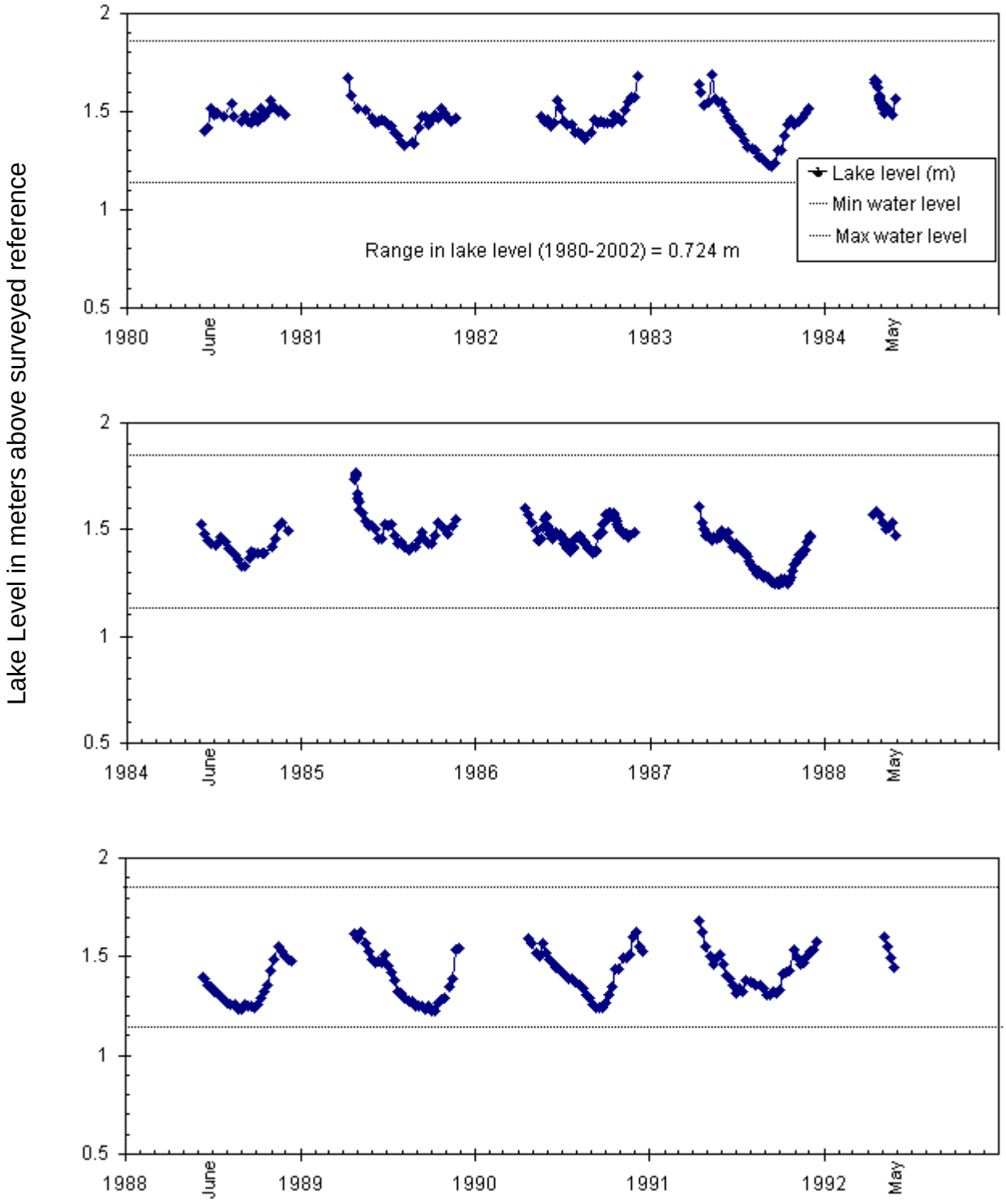
Crosson Lake Level

Lake Elevation 332 m ASL



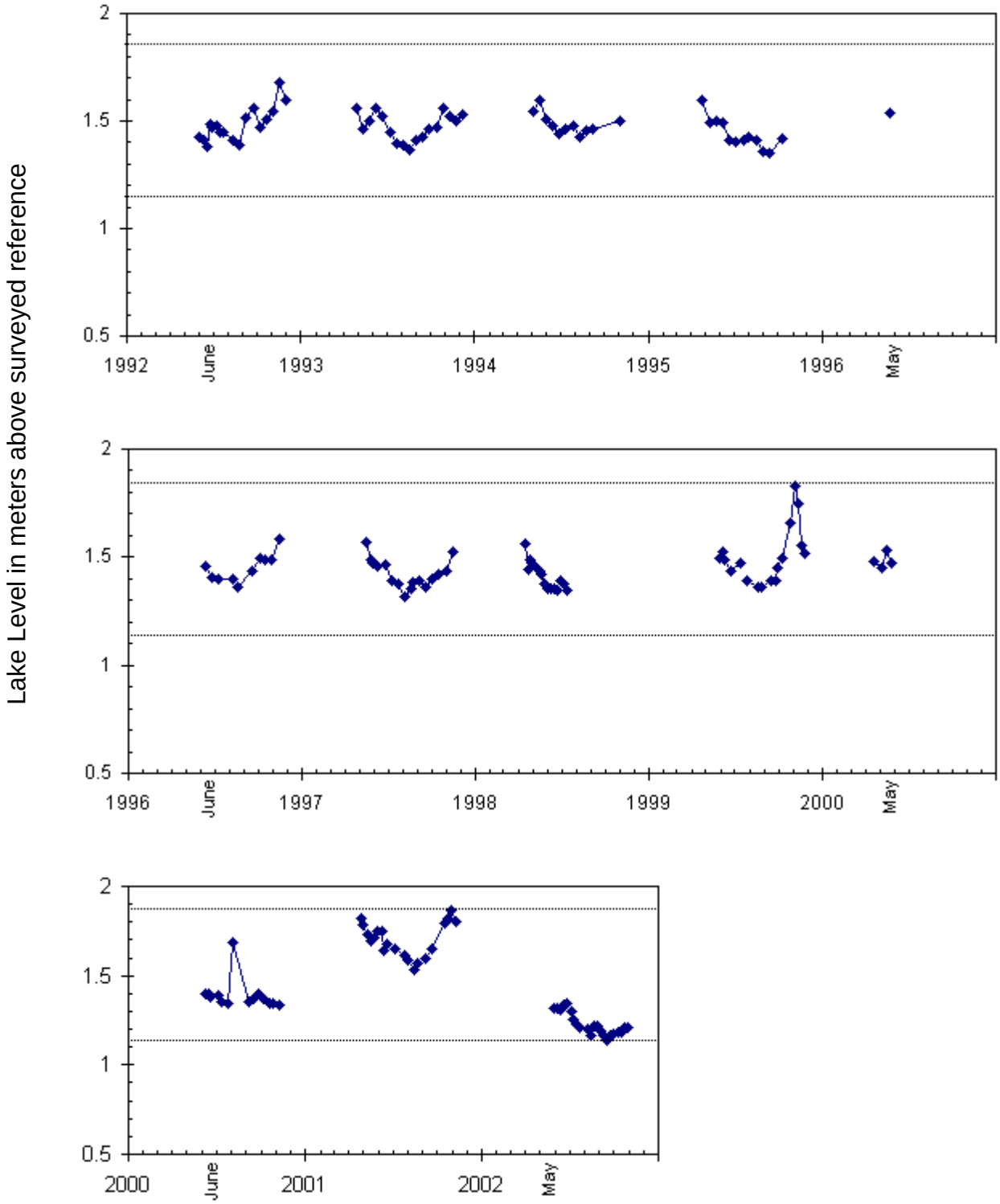
Dickie Lake Level

Lake Elevation 354.5 m ASL



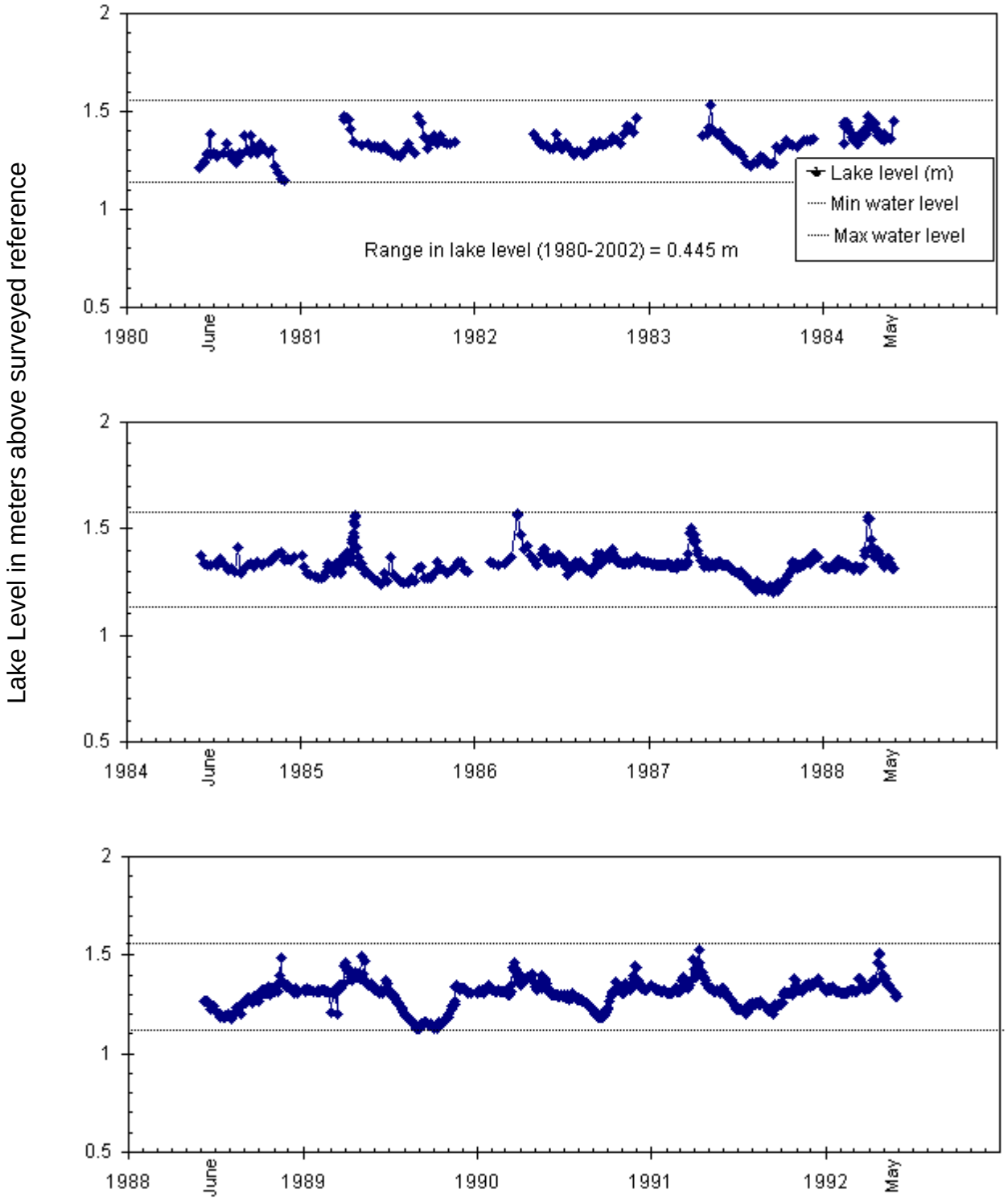
Dickie Lake Level

Lake Elevation 354.5 m ASL



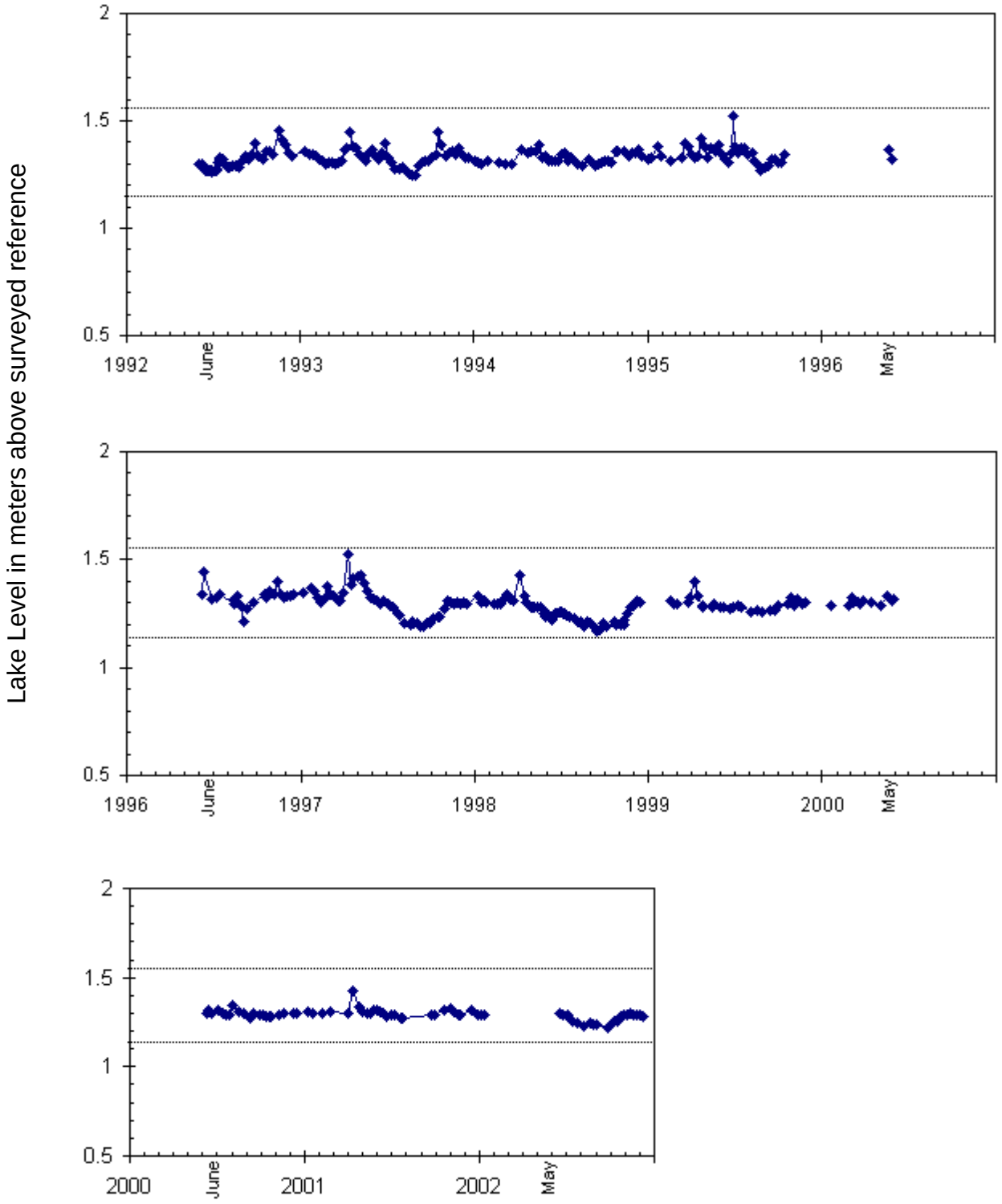
Harp Lake Level

Lake Elevation 327 m ASL



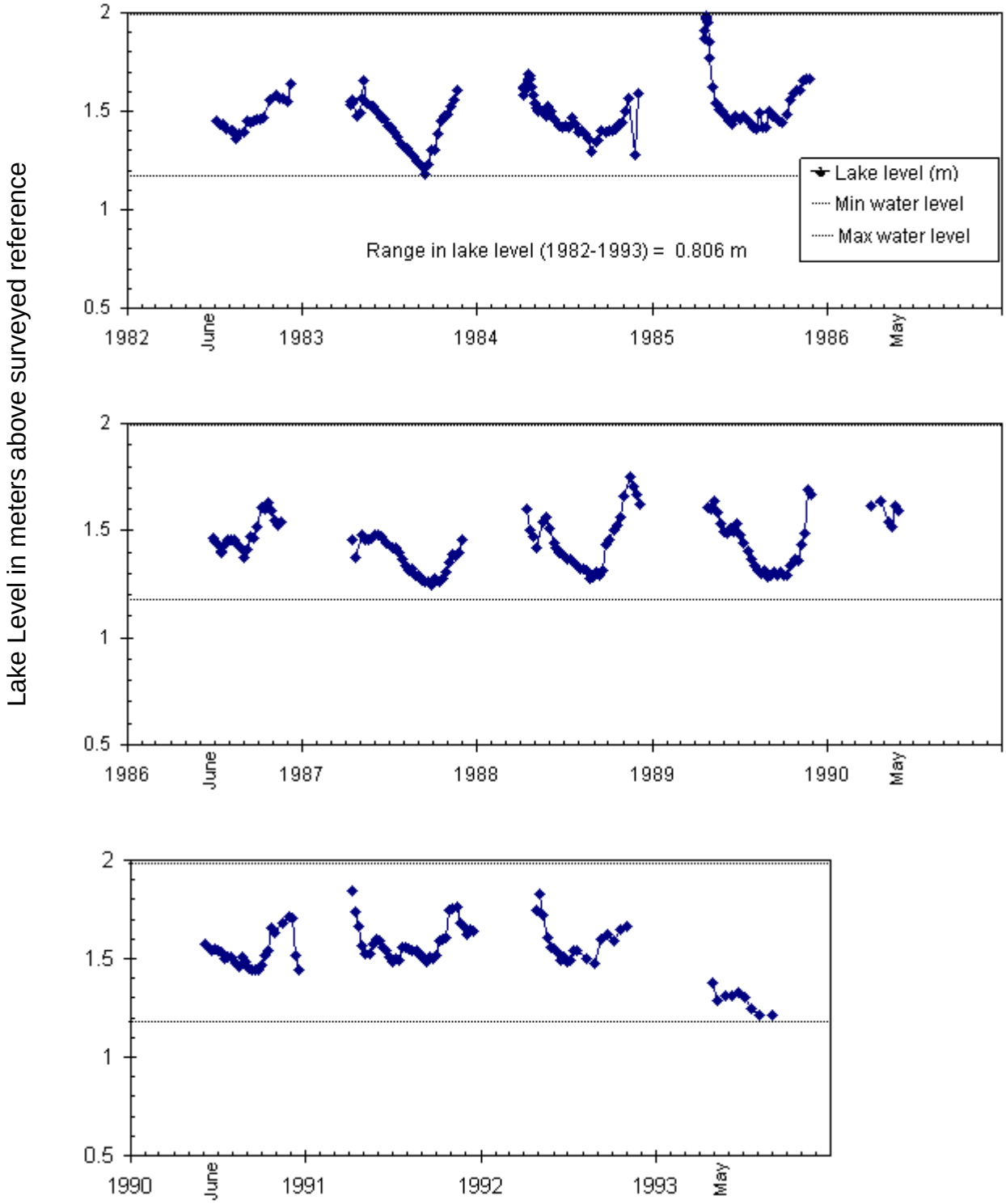
Harp Lake Level

Lake Elevation 327 m ASL



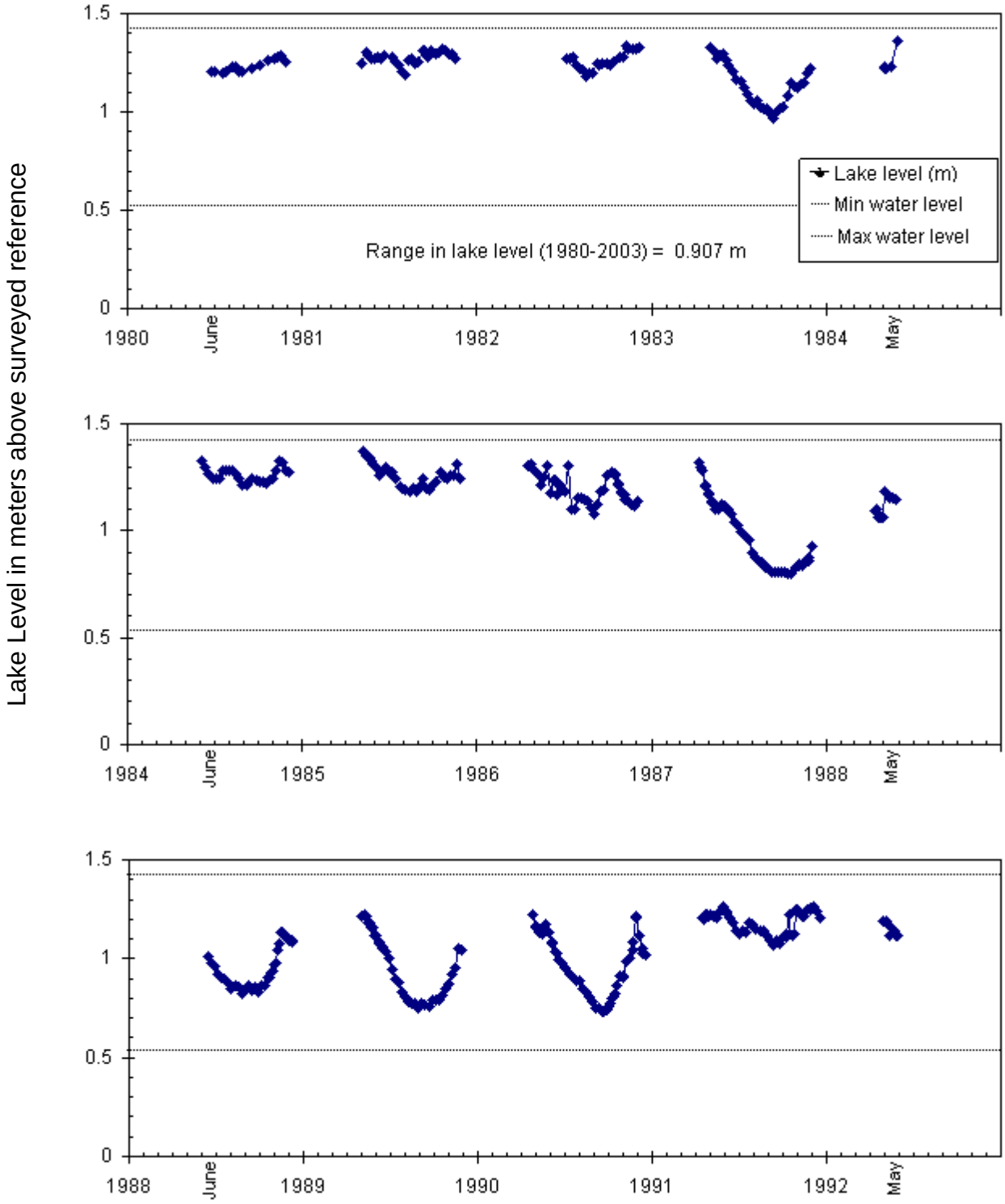
Heney Lake Level

Lake Elevation 345.5 m ASL



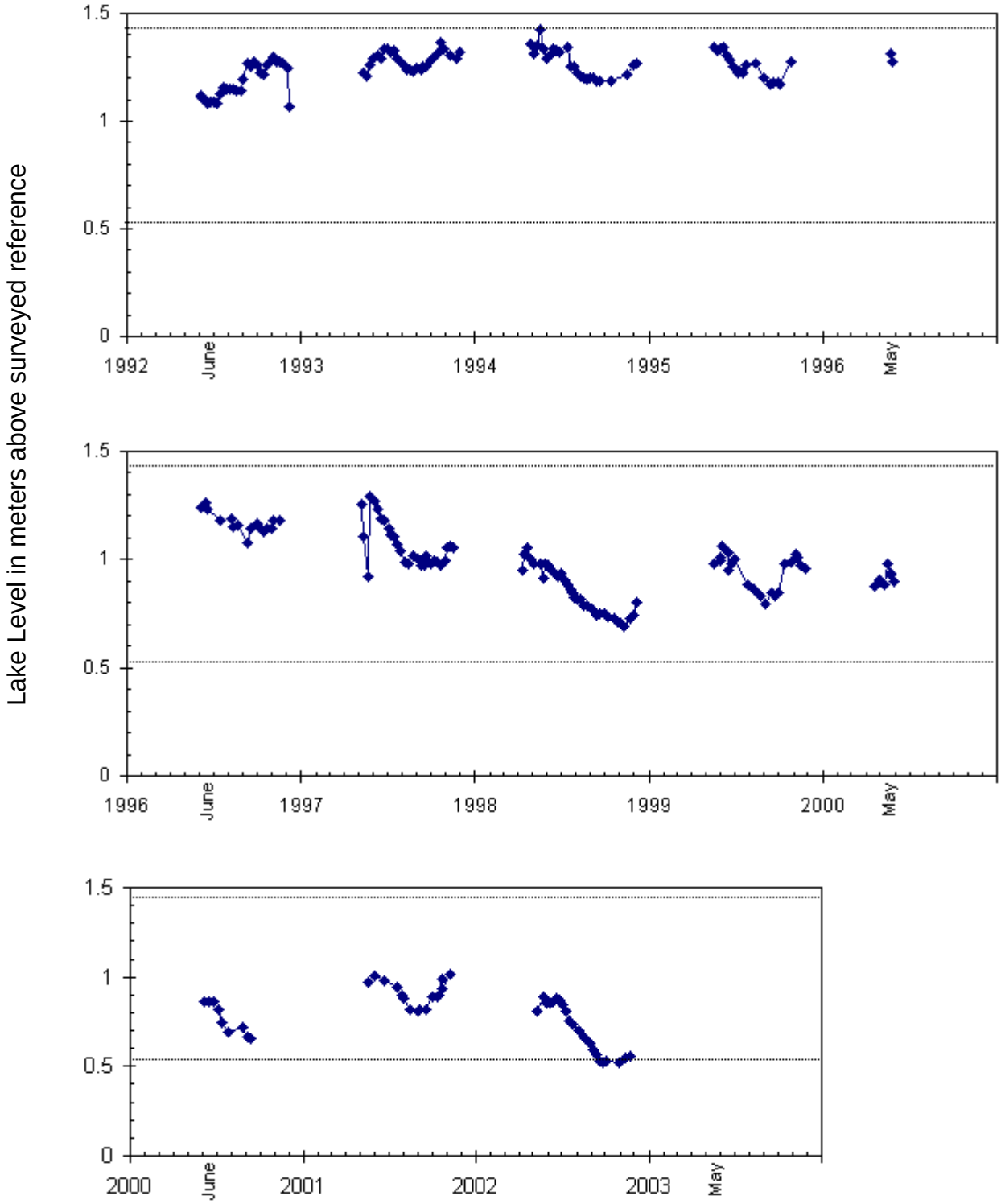
Plastic Lake Level

Lake Elevation 376.4 m ASL



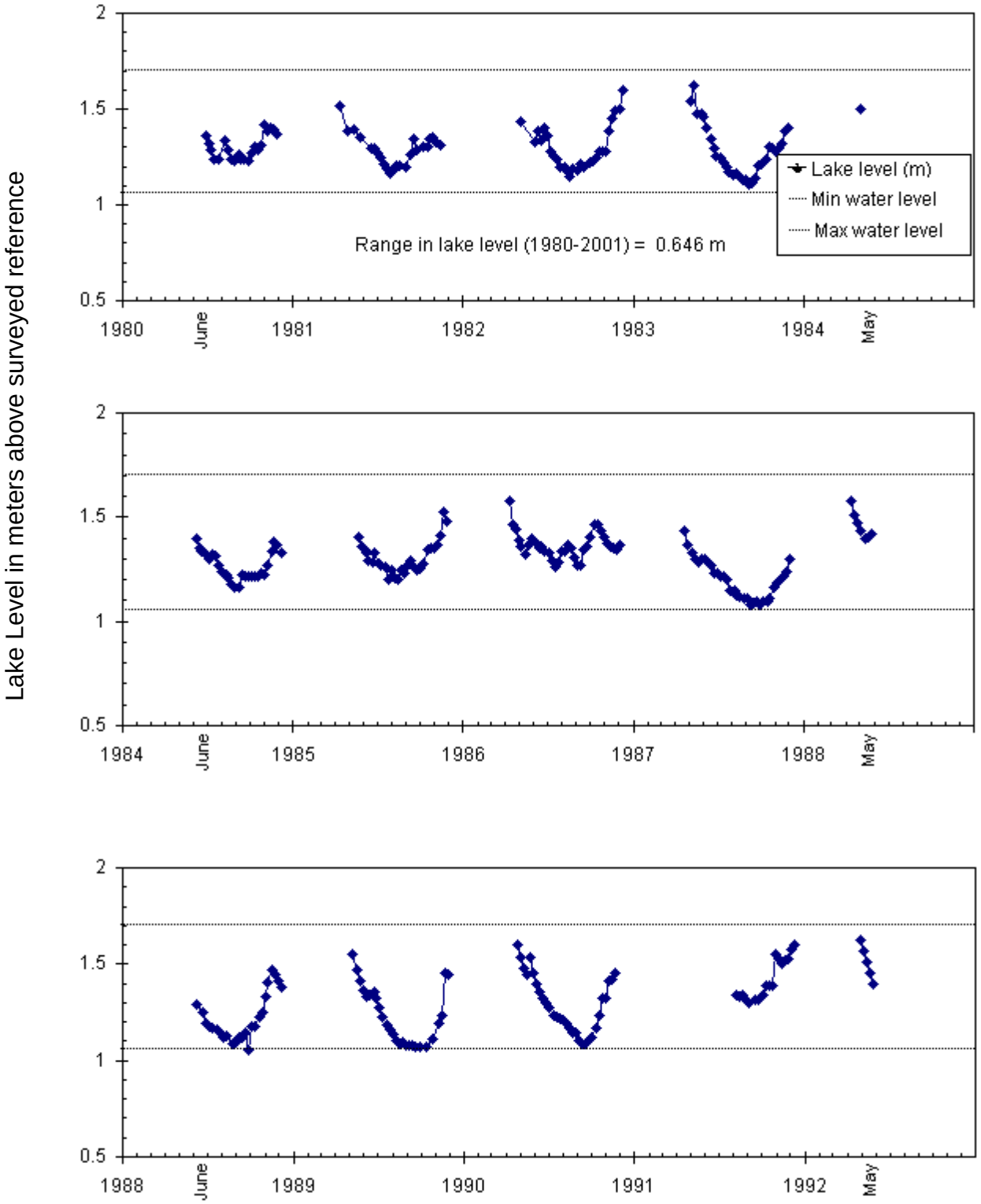
Plastic Lake Level

Lake Elevation 376.4 m ASL



Red Chalk Lake Level

Lake Elevation 343 m ASL



Red Chalk Lake Level

Lake Elevation 343 m ASL

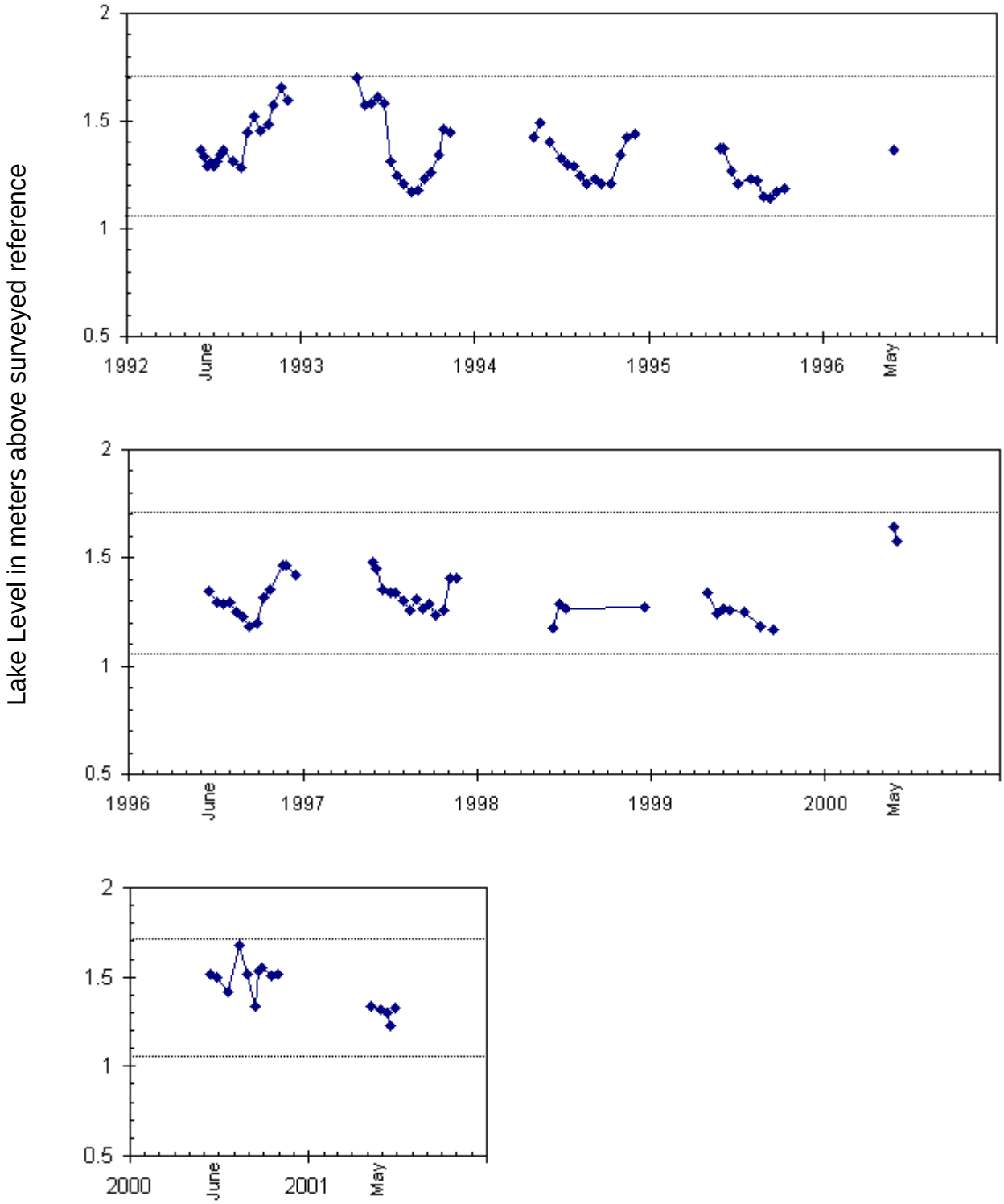
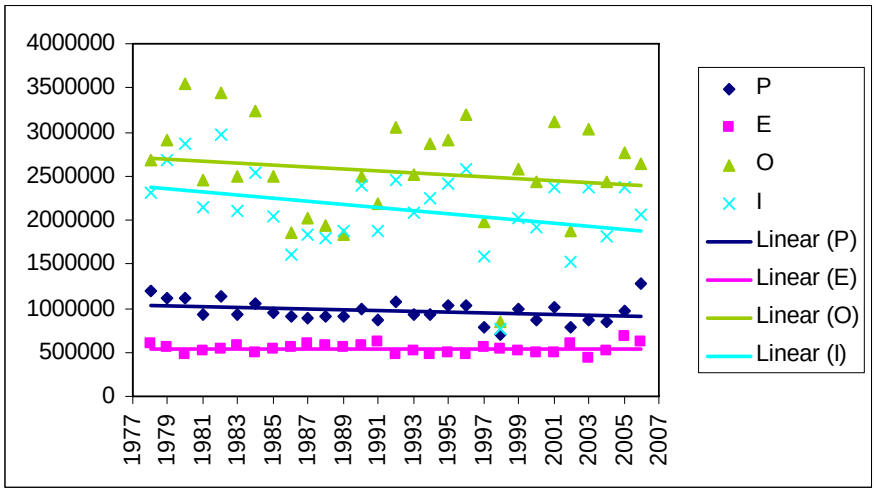
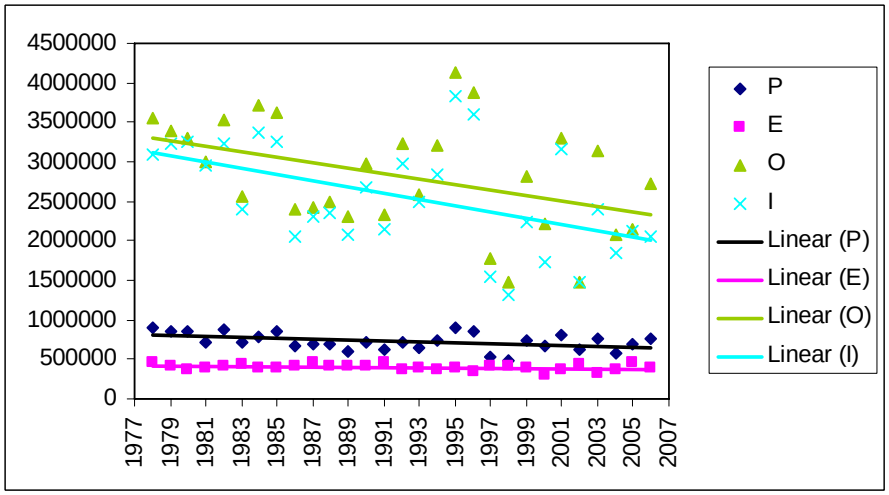


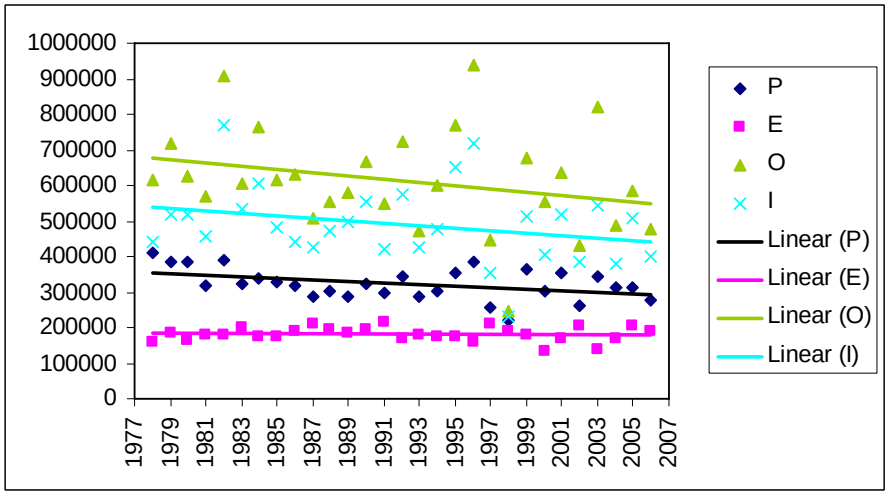
Figure 6 Long-term trends in lake water balance terms



Dickie Lake



Harp Lake

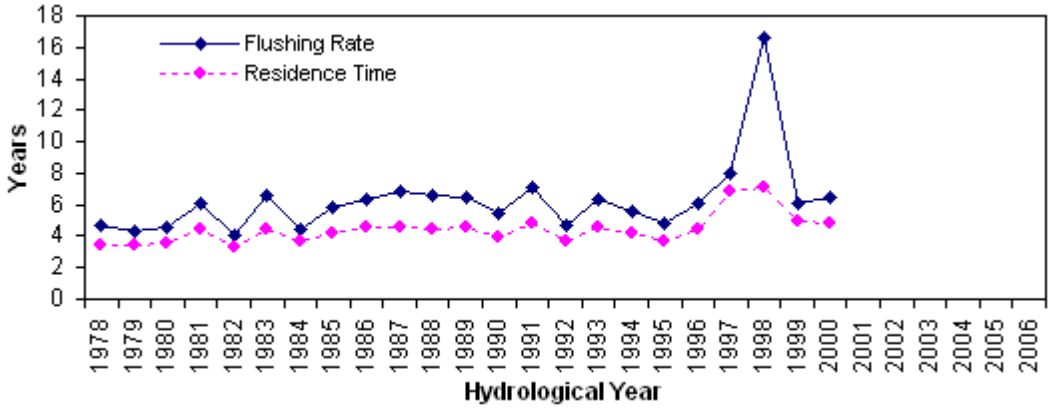


Plastic Lake

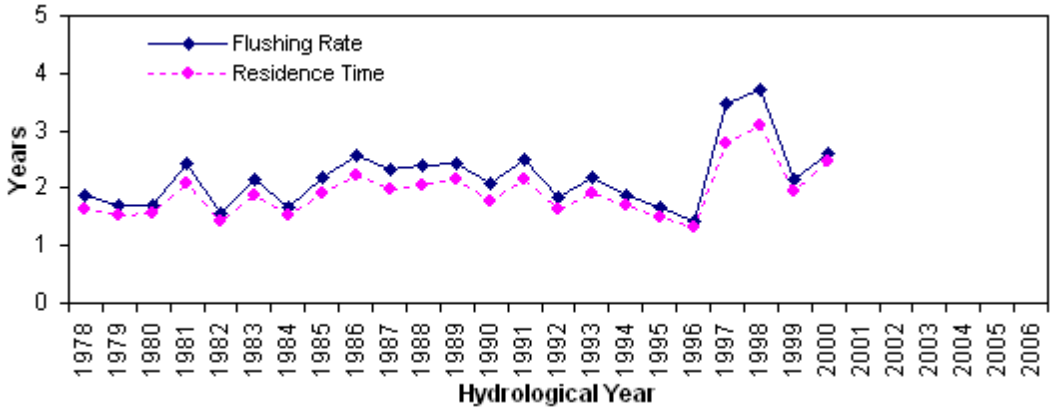
Figure 7 Annual residence and flushing time for eight lakes, 1978-2007

Blue Chalk
Chub
Crosson
Dickie
Harp
Heney
Plastic
Red Chalk

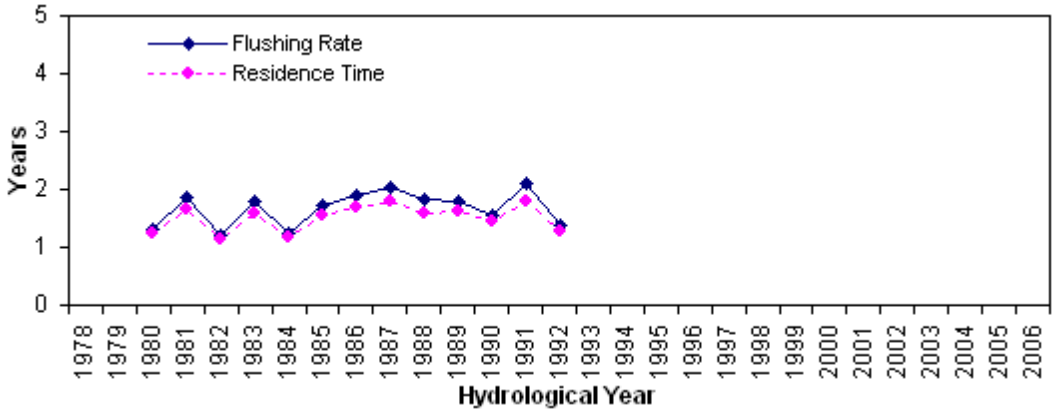
Blue Chalk Lake



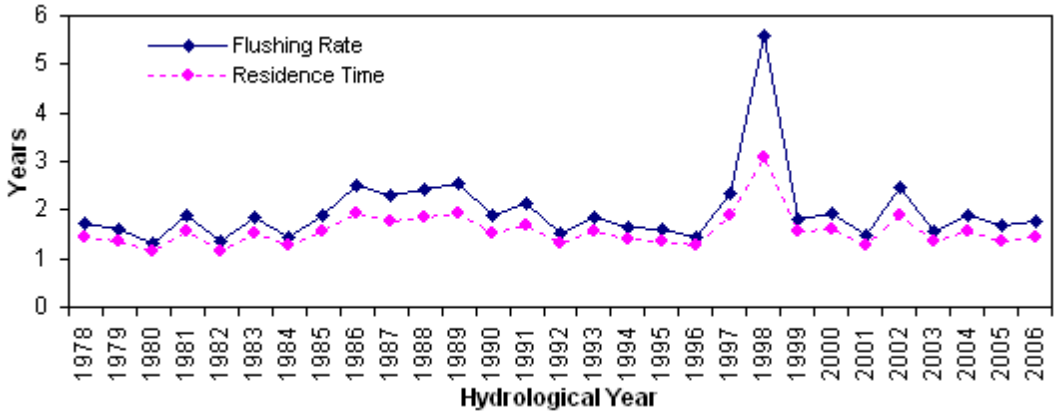
Chub Lake



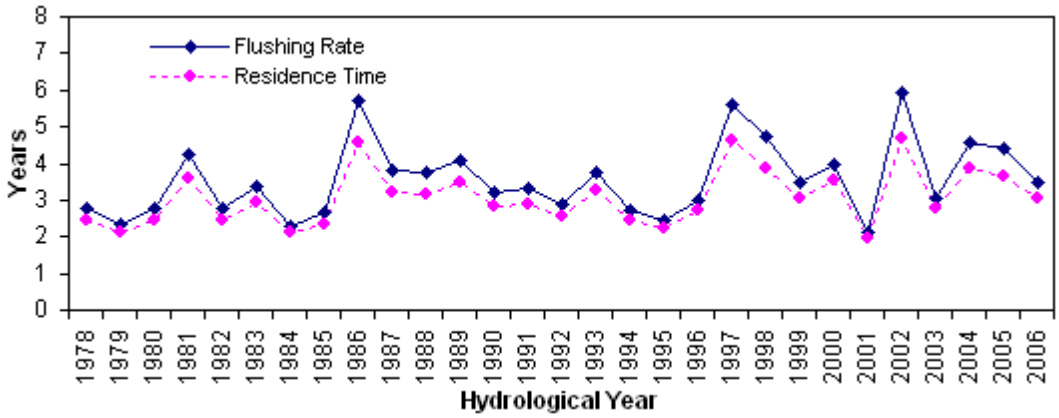
Crosson Lake



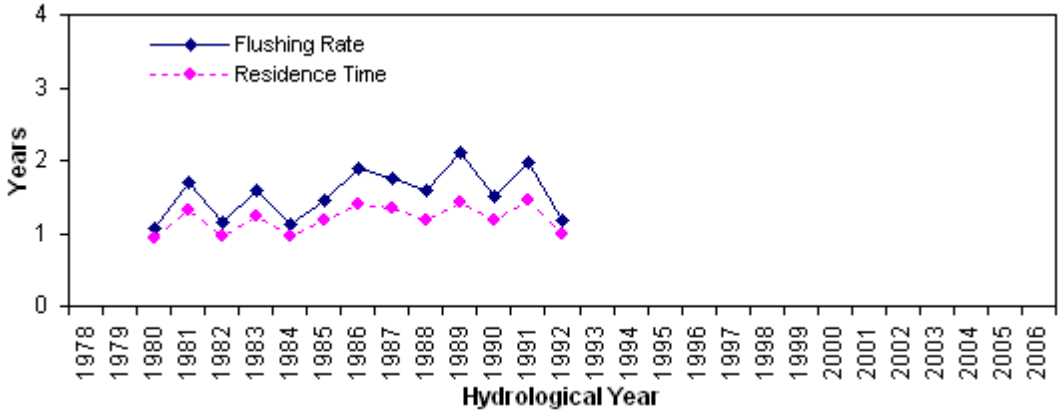
Dickie Lake



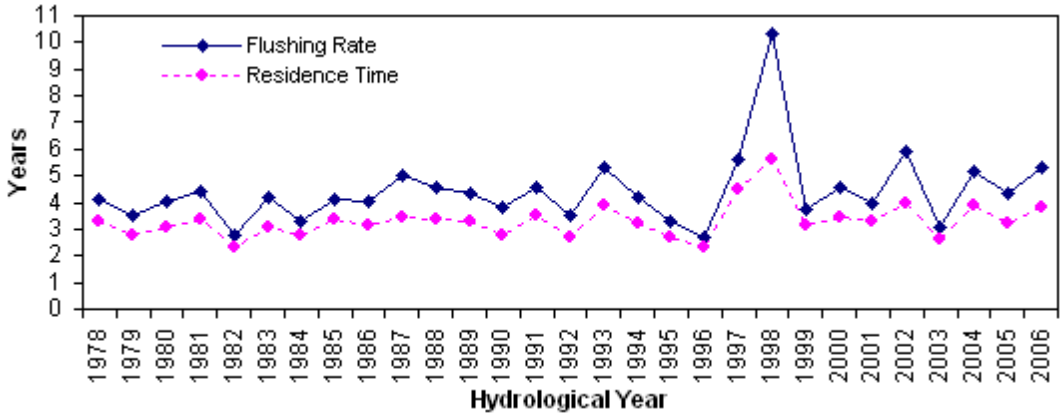
Harp Lake



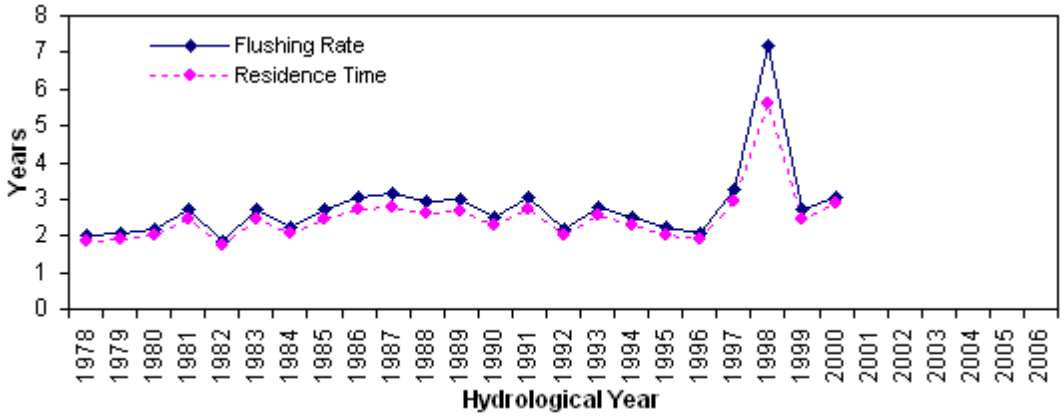
Heney Lake



Plastic Lake



Red Chalk Lake

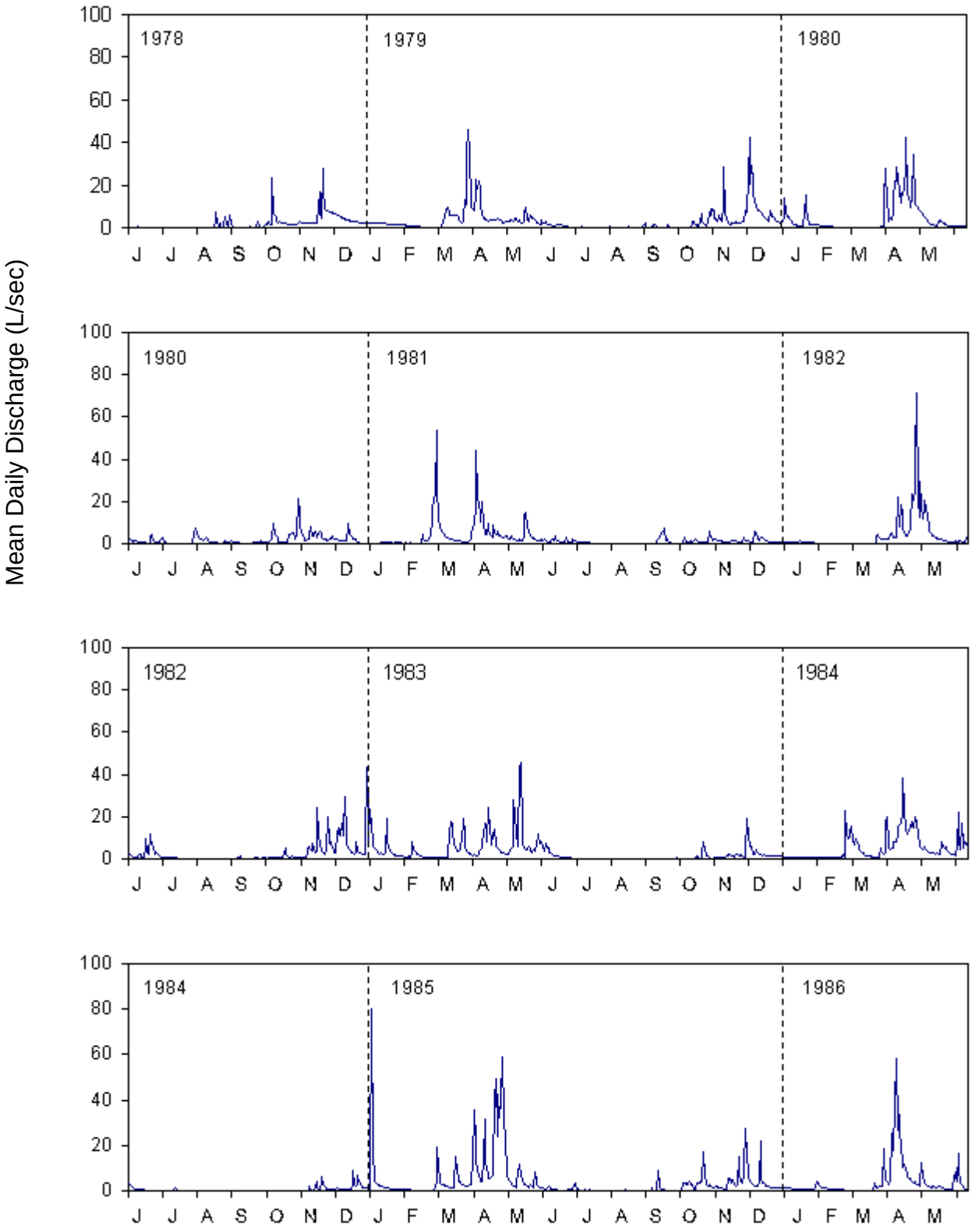


Appendix A

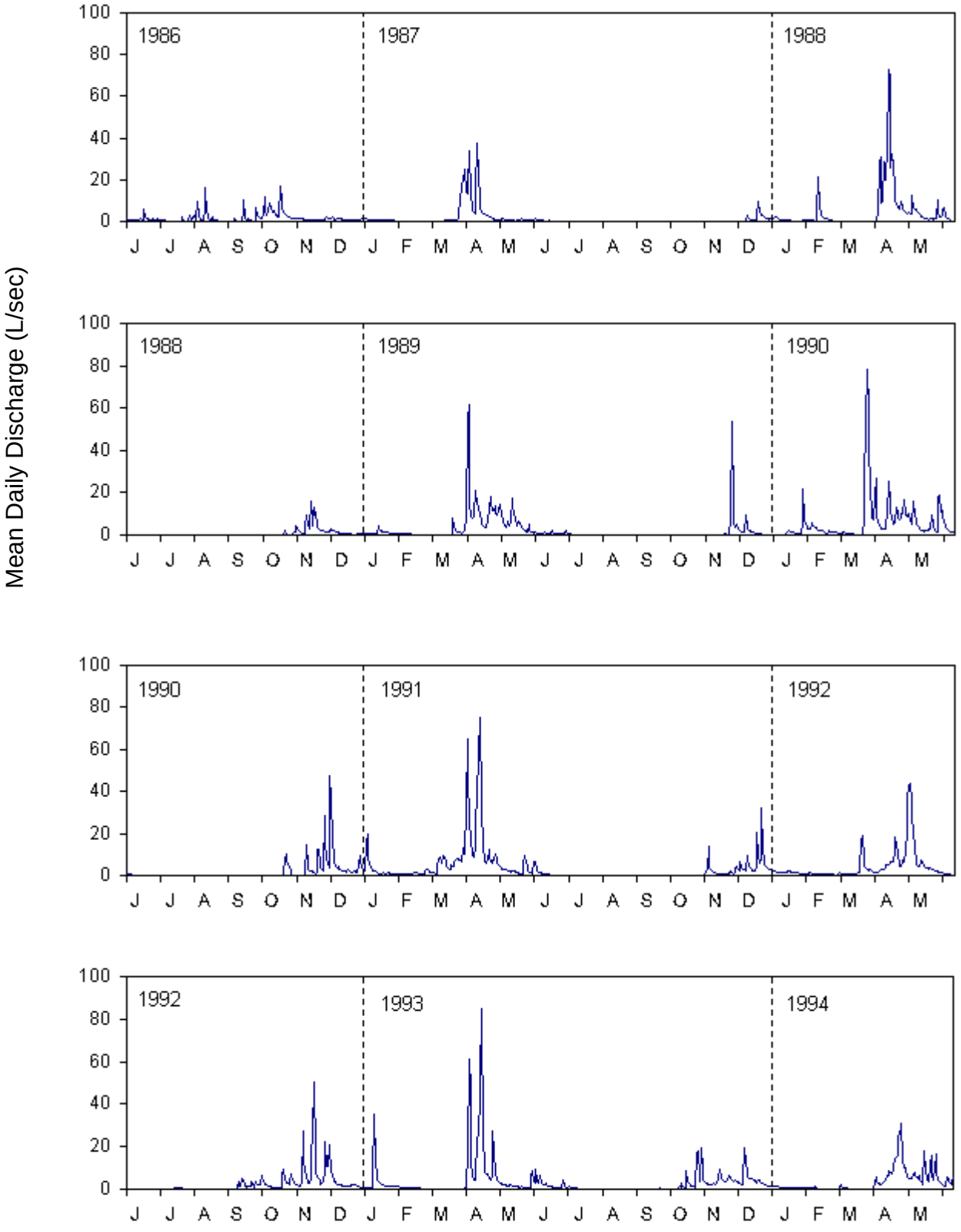
Mean daily discharges (L/sec) for 20 inlet streams draining to the 8 lakes, 1978-2007

Blue Chalk 1	1978-2001
Chub 1	1978-2001
Chub 2	1978-2001
Crosson 1	1980-1993
Dickie 5	1978-2007
Dickie 6	1978-2007
Dickie 8	1978-2007
Dickie 10	1978-2007
Dickie 11	1978-2007
Harp 3	1978-2007
Harp 3a	1978-2007
Harp 4	1978-2007
Harp 5	1978-2007
Harp 6	1978-2007
Harp 6a	1978-2007
Plastic 1	1978-2007
Red Chalk 1	1978-2001
Red Chalk 2	1978-2001
Red Chalk 3	1978-2001
Red Chalk 4	1978-2001

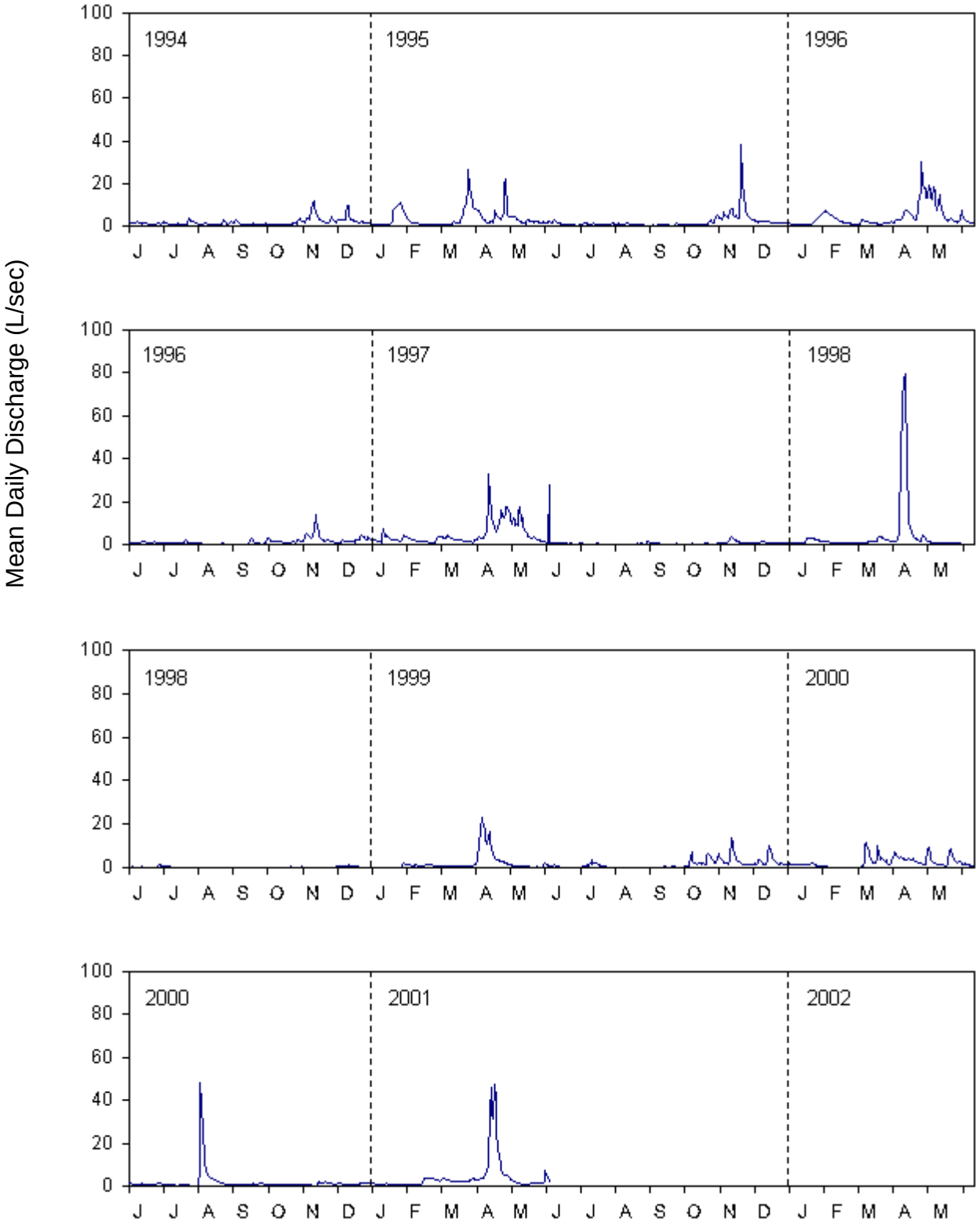
Blue Chalk Inflow 1 Hydrograph



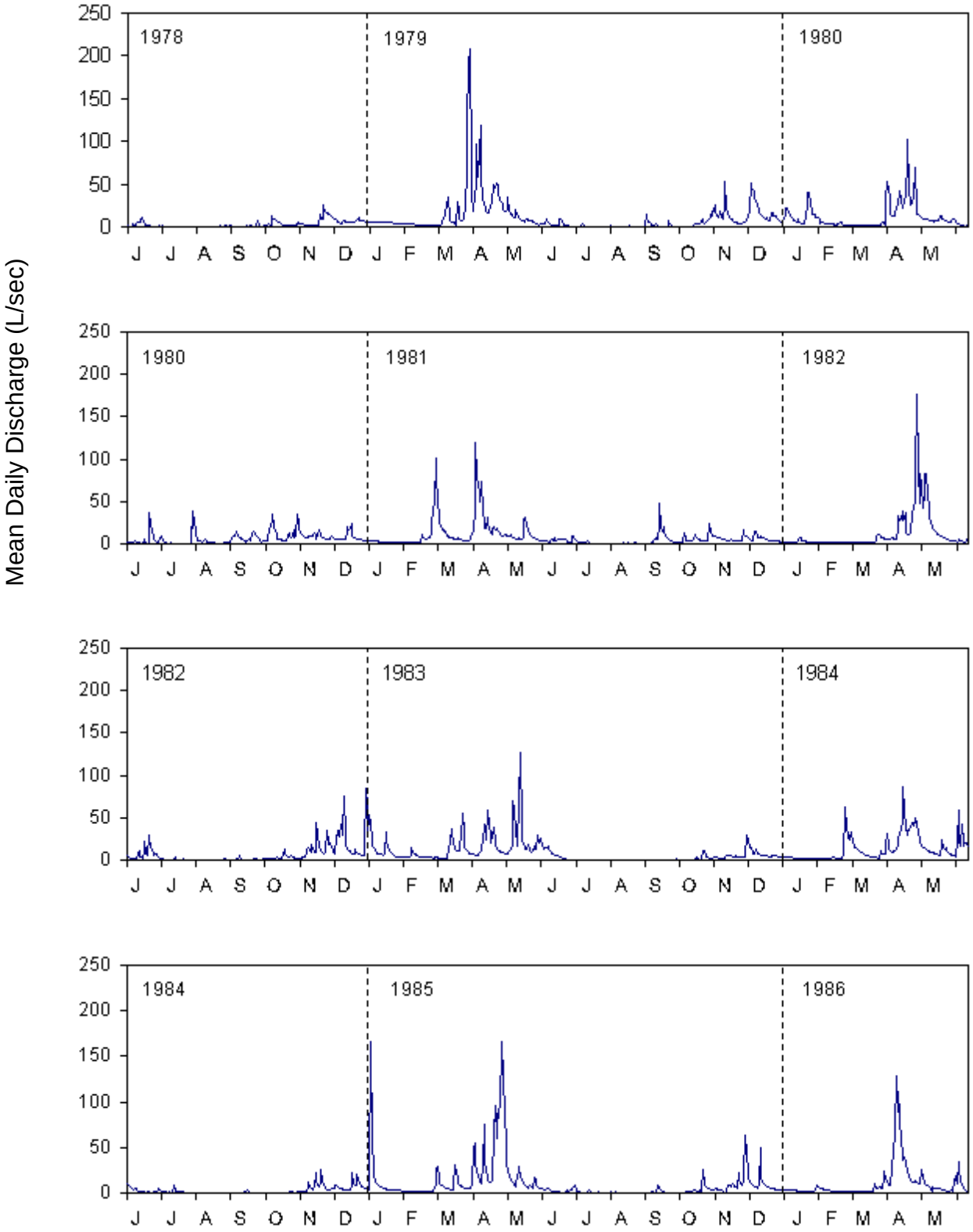
Blue Chalk Inflow 1 Hydrograph



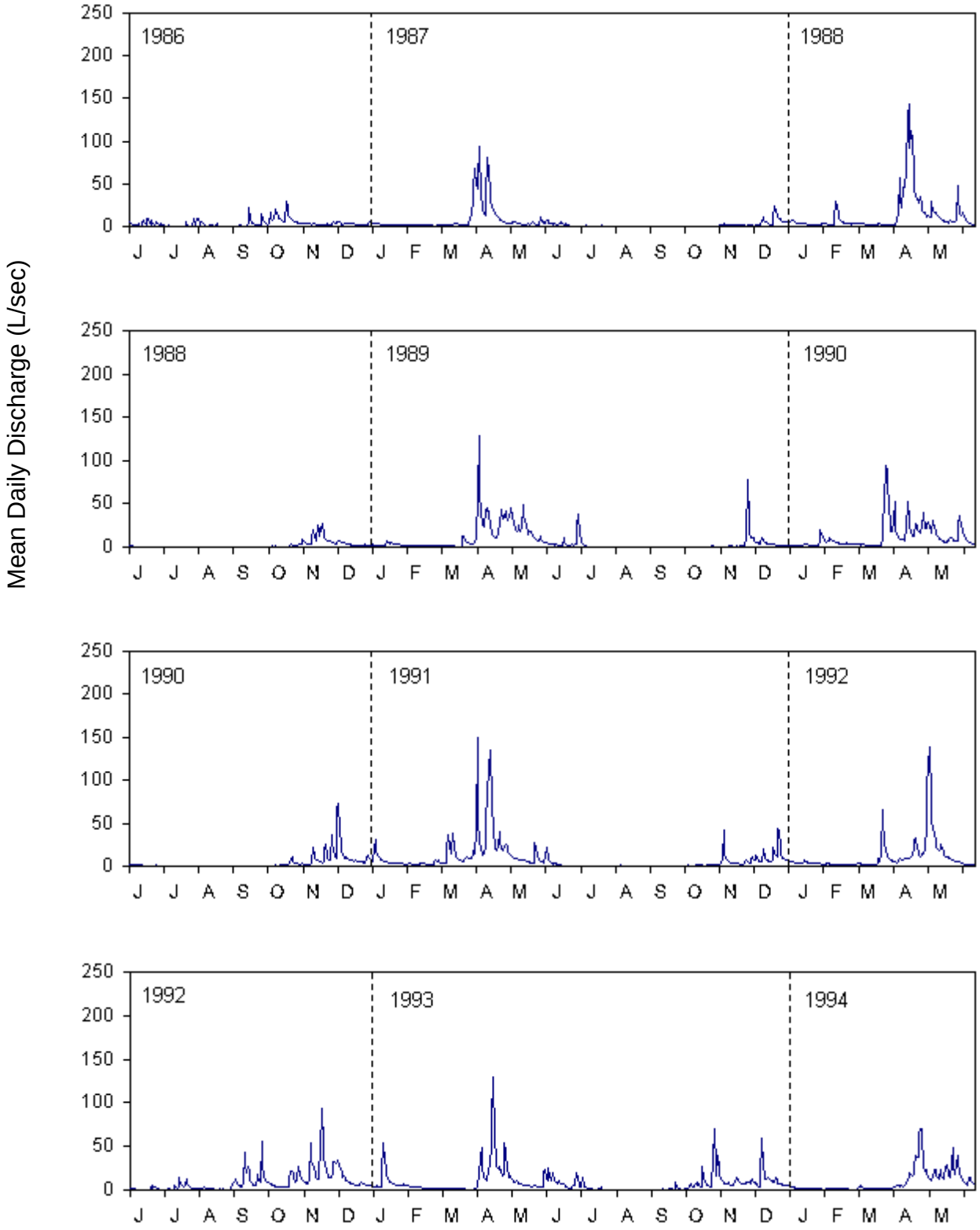
Blue Chalk Inflow 1 Hydrograph



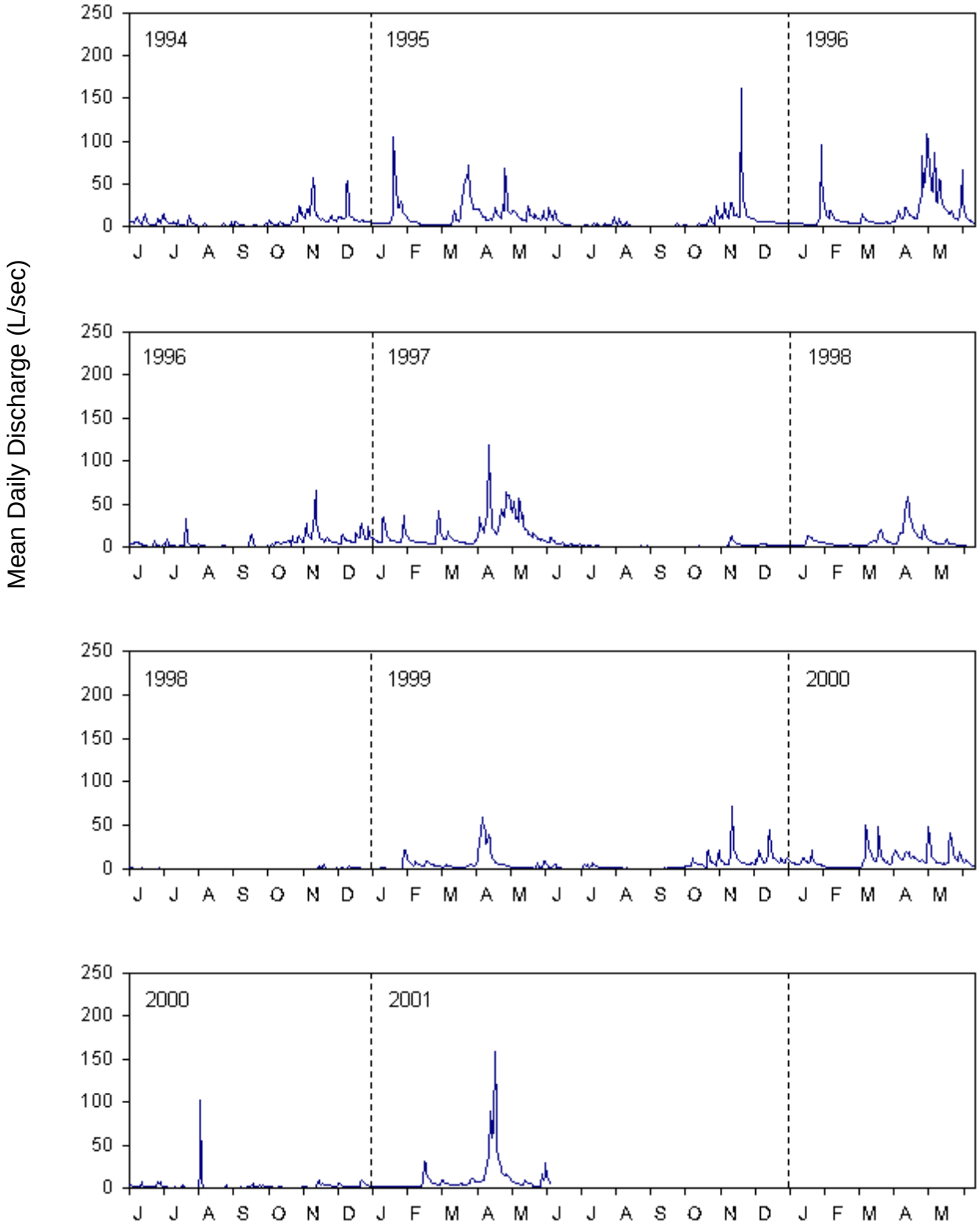
Chub Inflow 1 Hydrograph



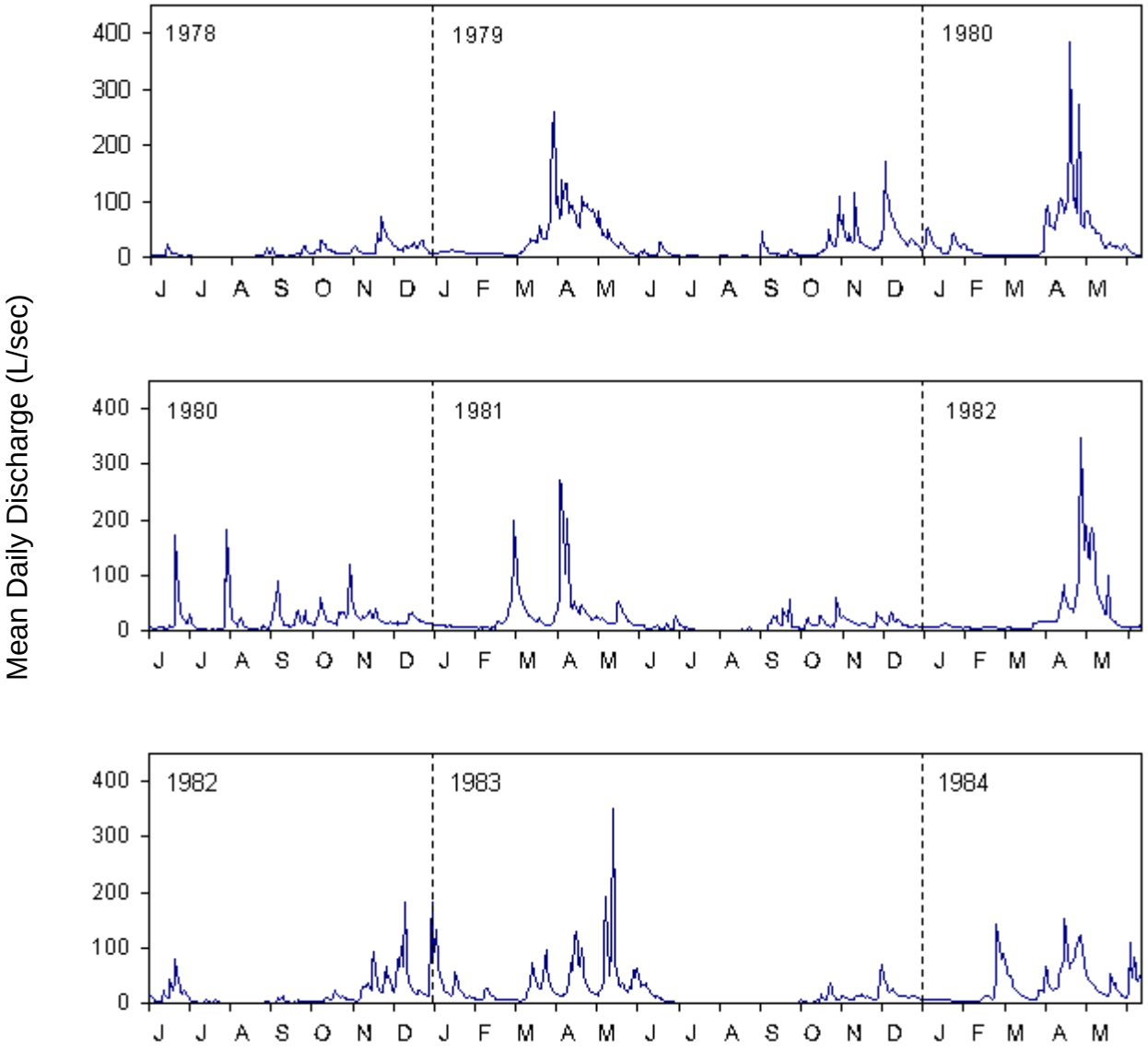
Chub Inflow 1 Hydrograph

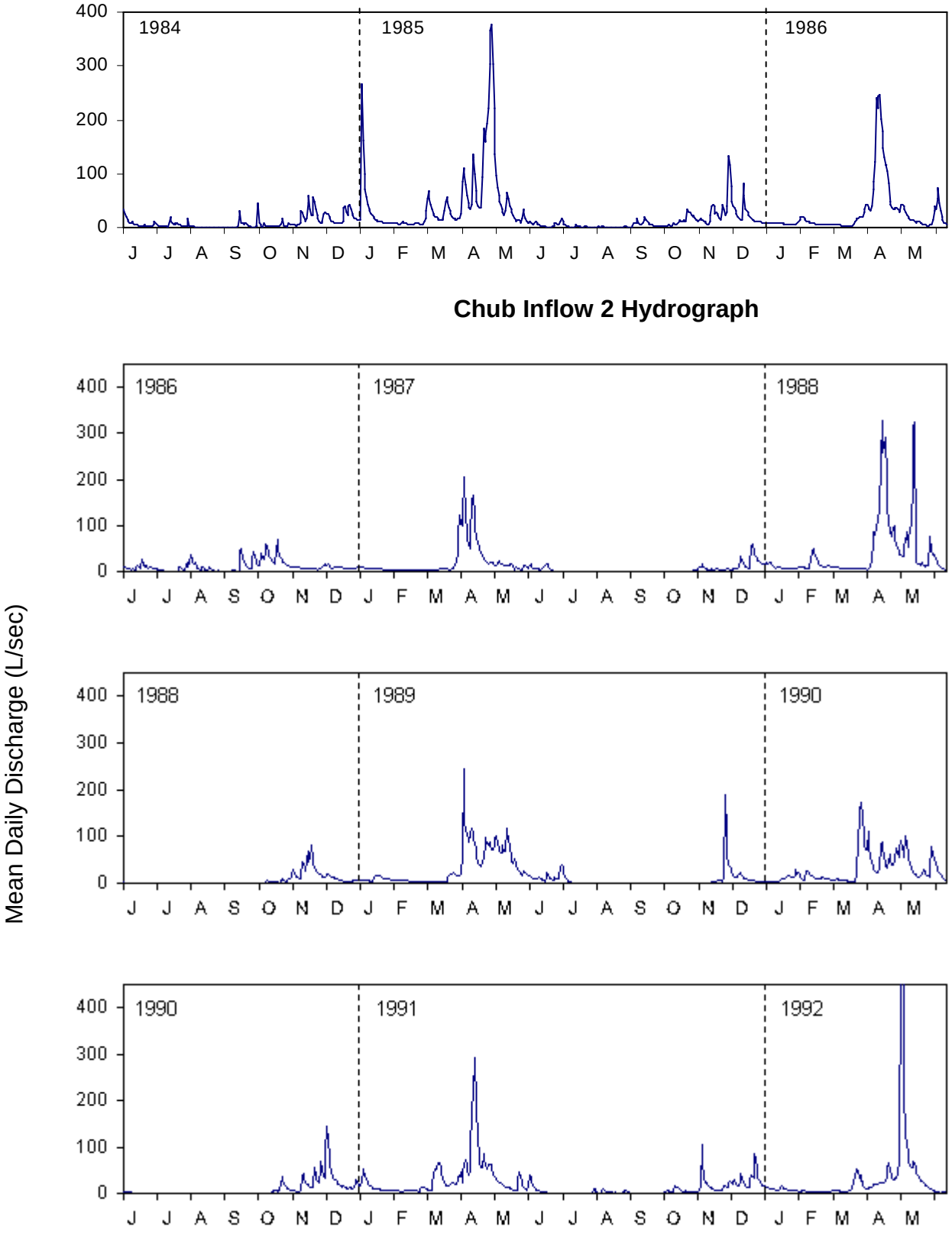


Chub Inflow 1 Hydrograph

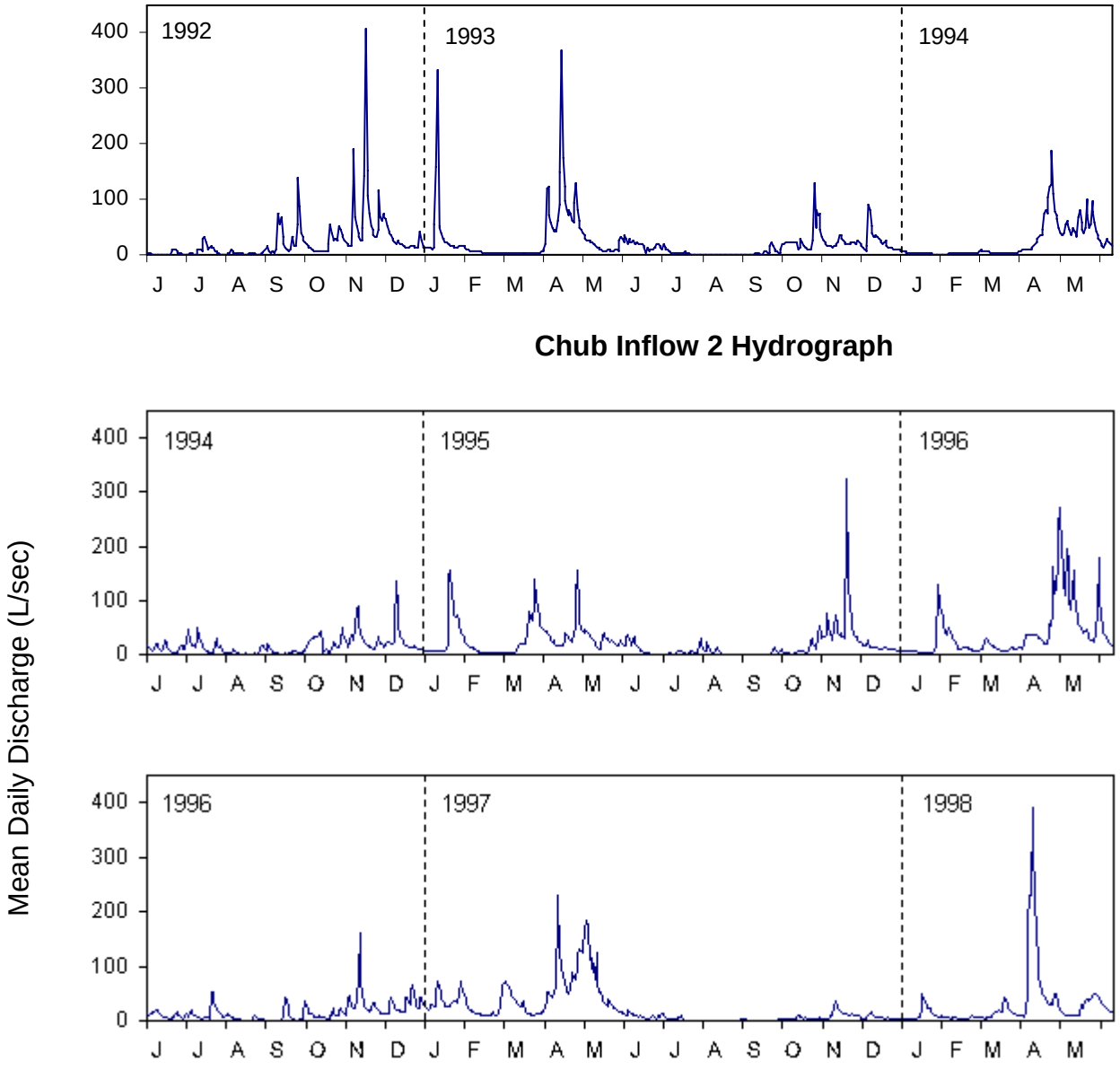


Chub Inflow 2 Hydrograph

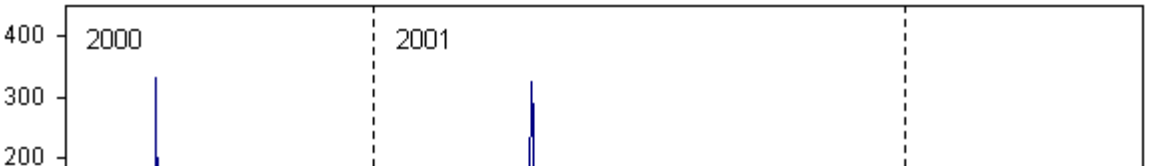


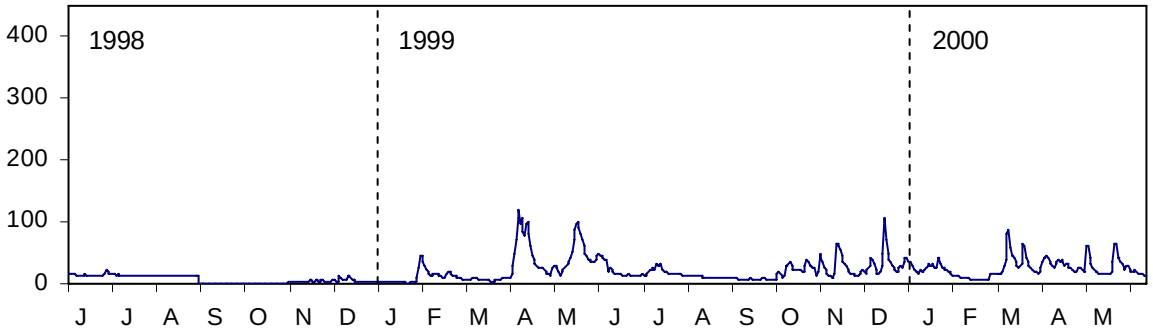


Chub Inflow 2 Hydrograph

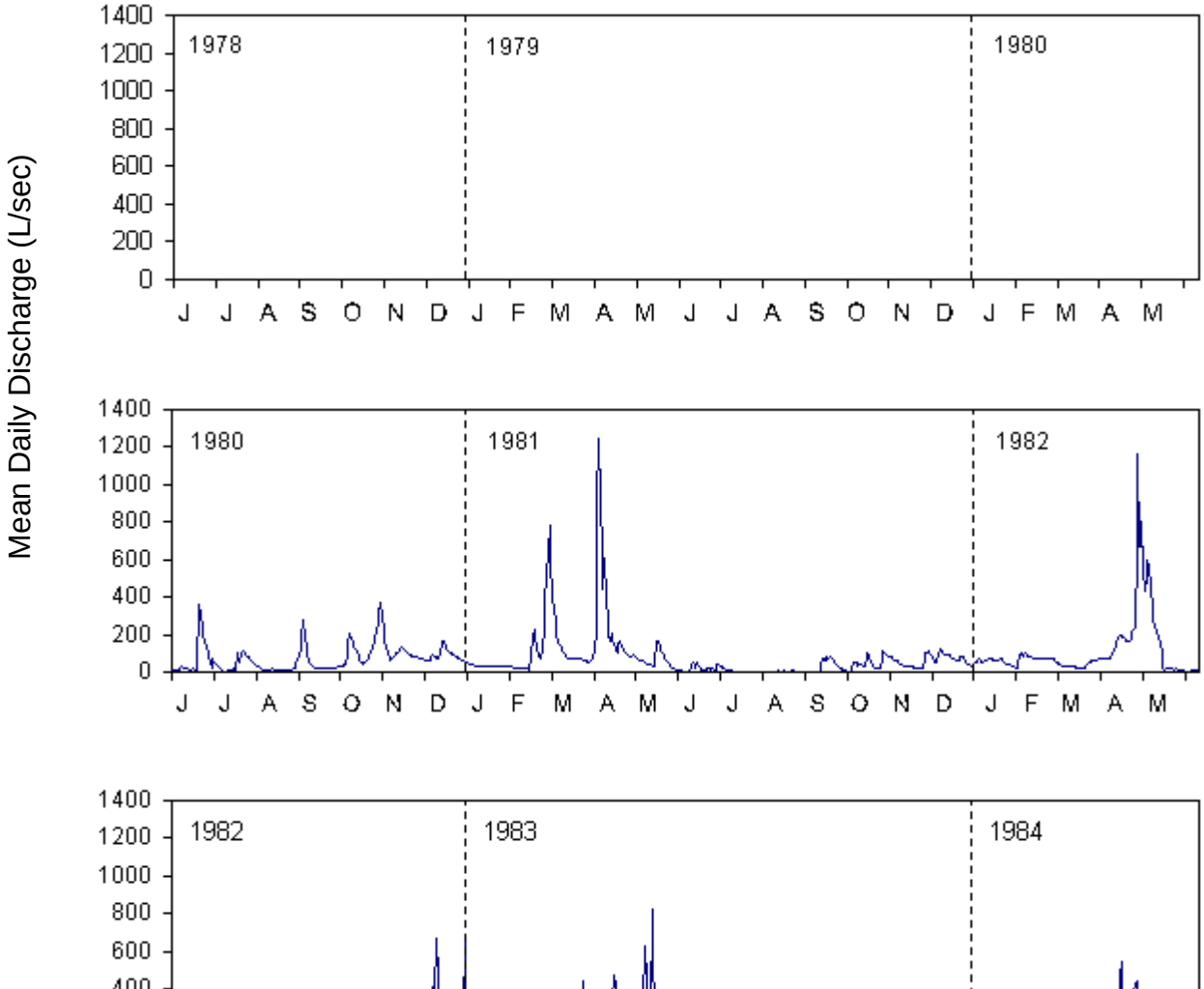


Chub Inflow 2 Hydrograph

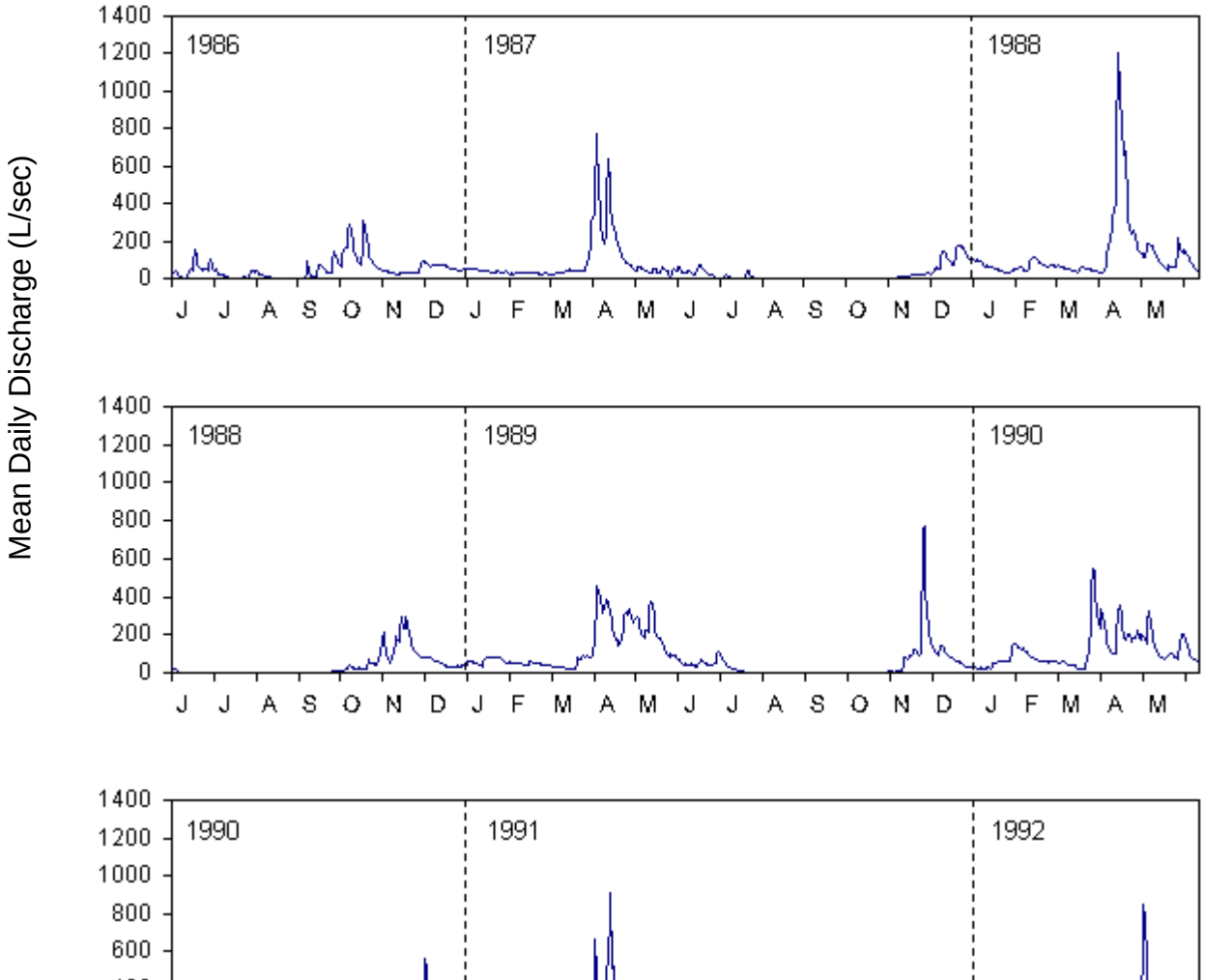




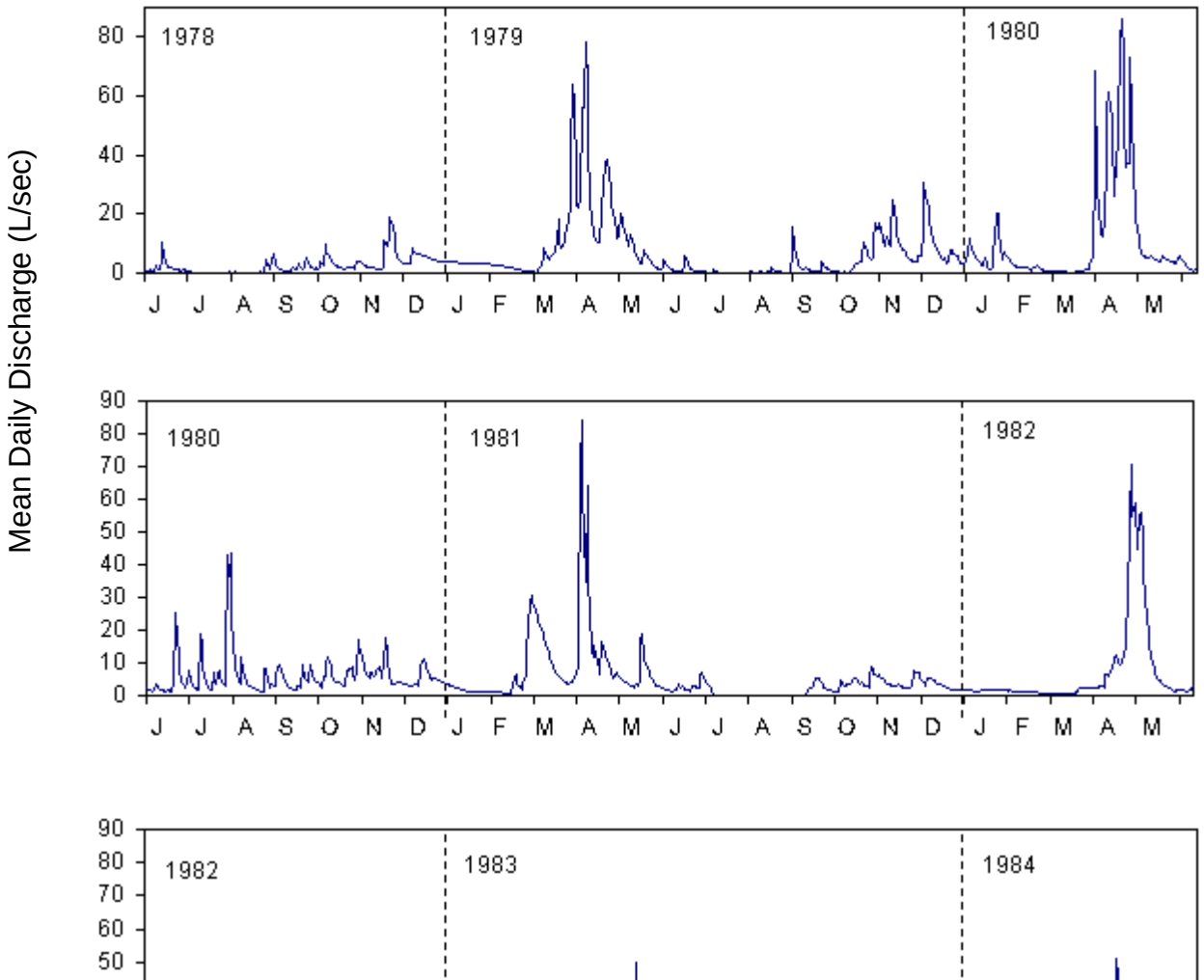
Crosson Inflow 1 Hydrograph



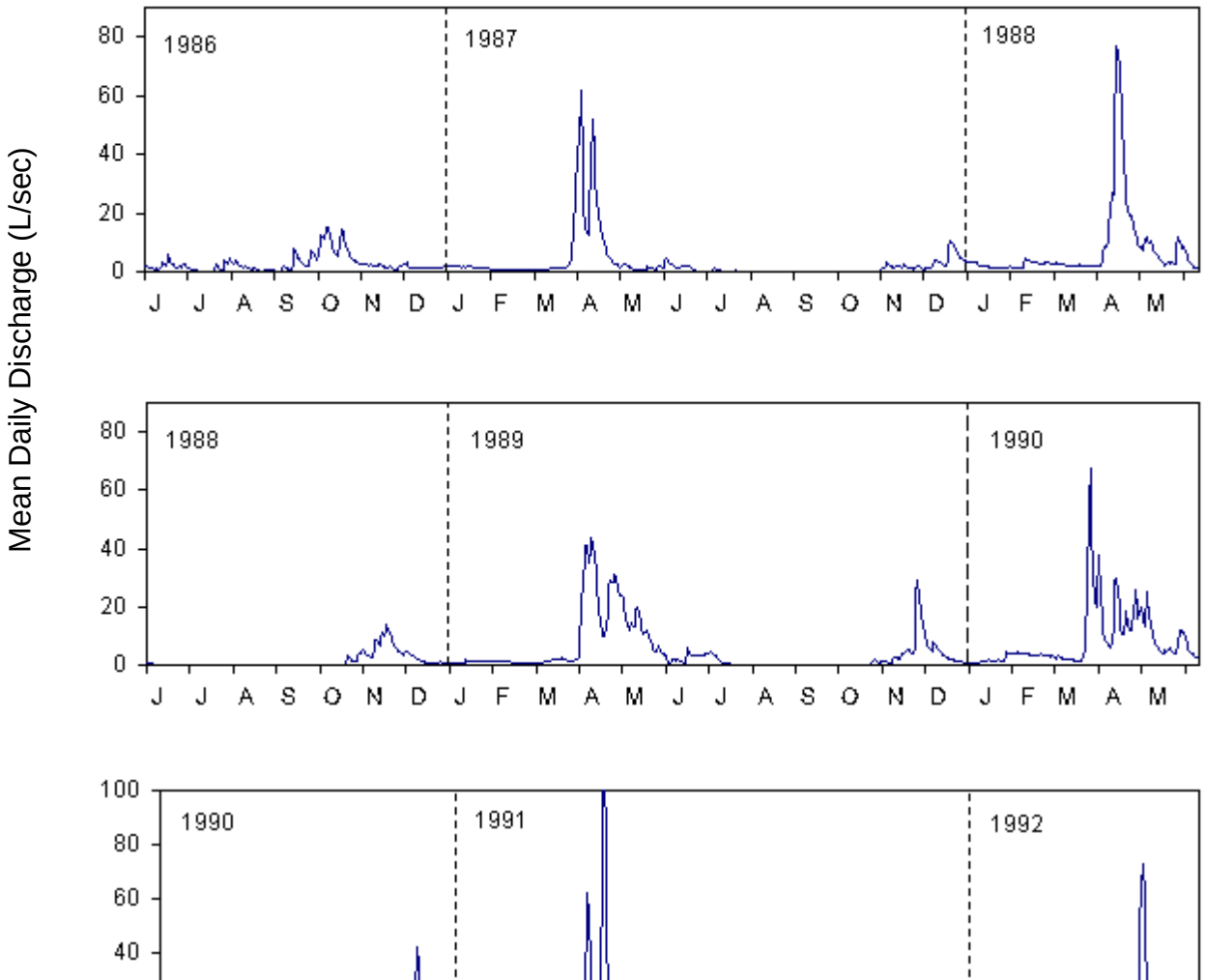
Crosson Inflow 1 Hydrograph
Crosson Inflow 1 Hydrograph



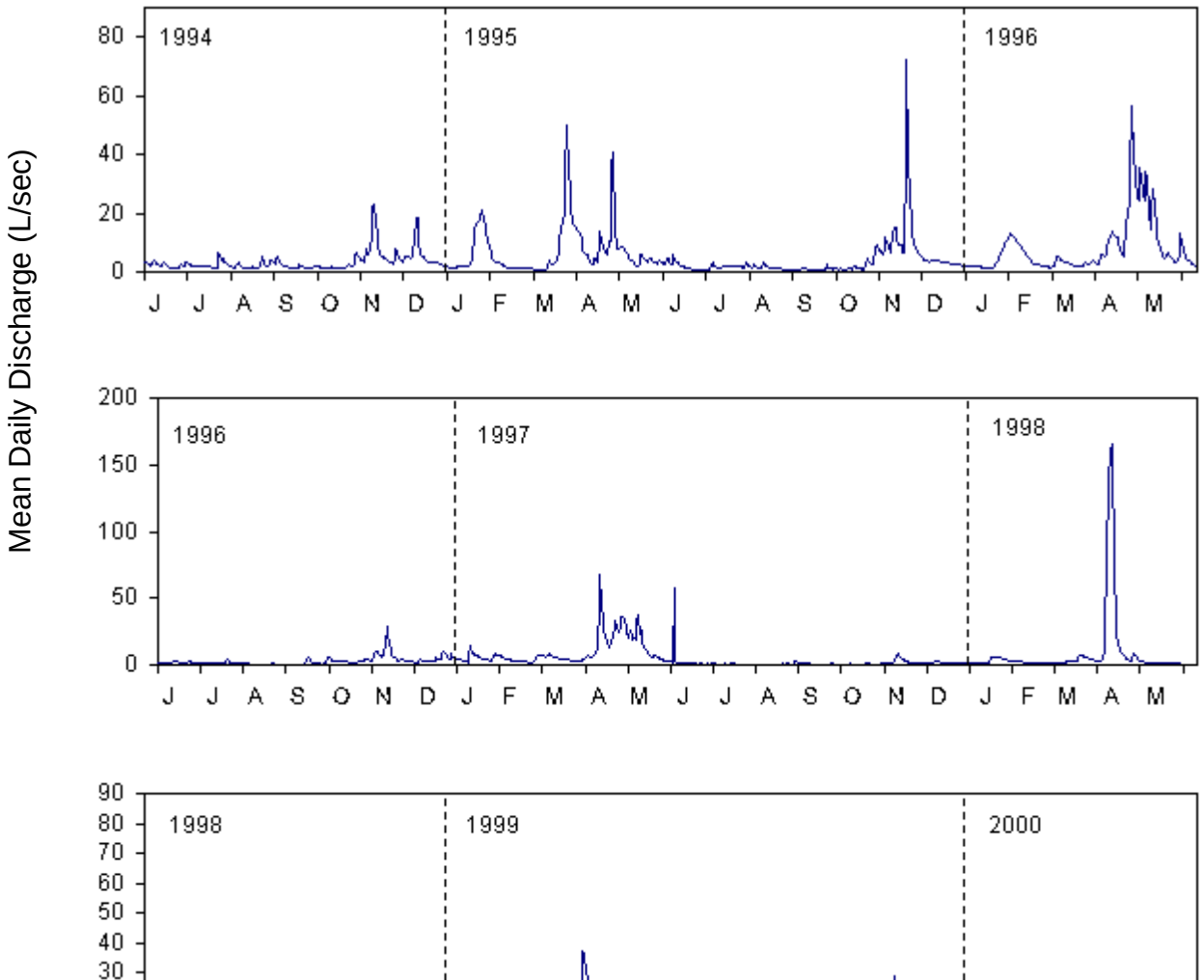
Dickie Inflow 5 Hydrograph



Dickie Inflow 5 Hydrograph



Dickie Inflow 5 Hydrograph



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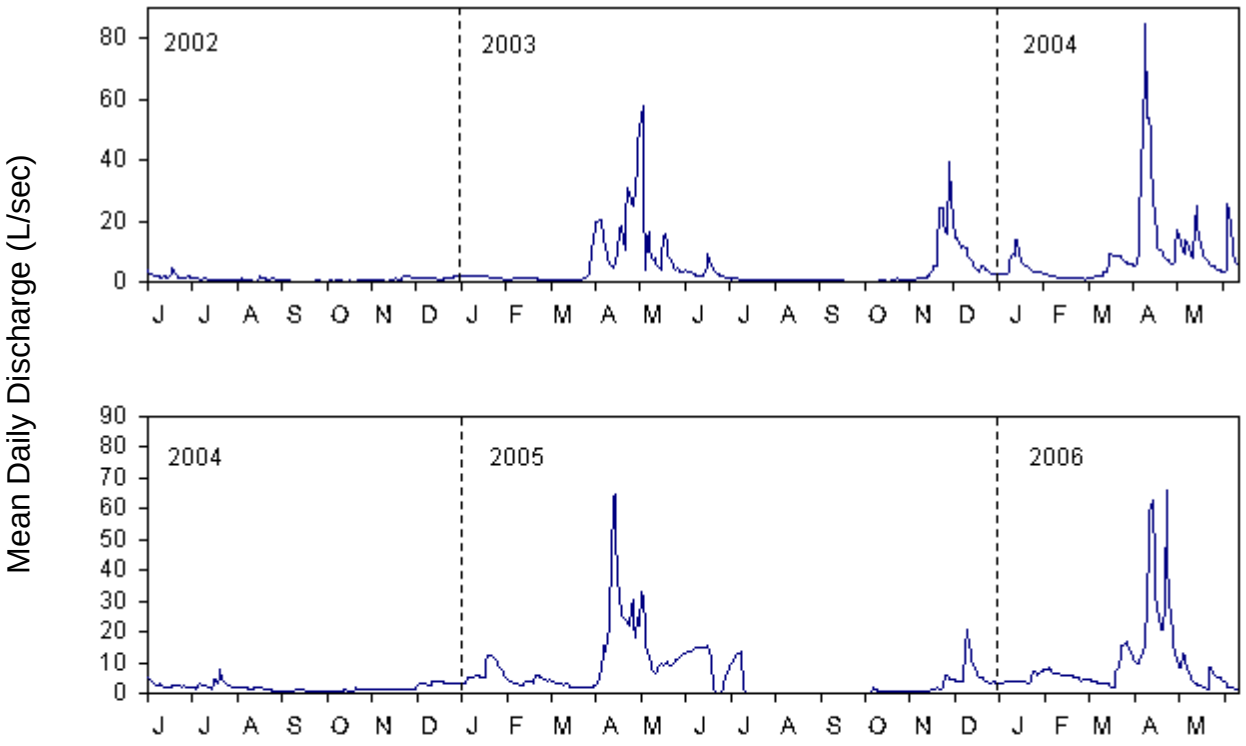
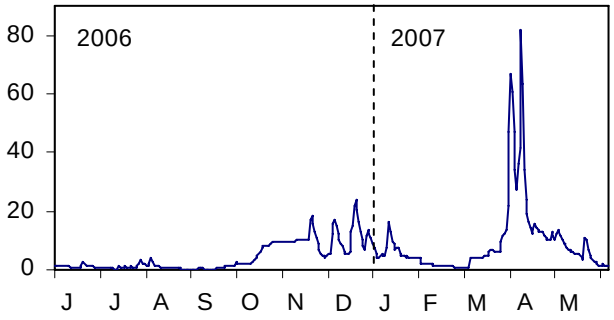
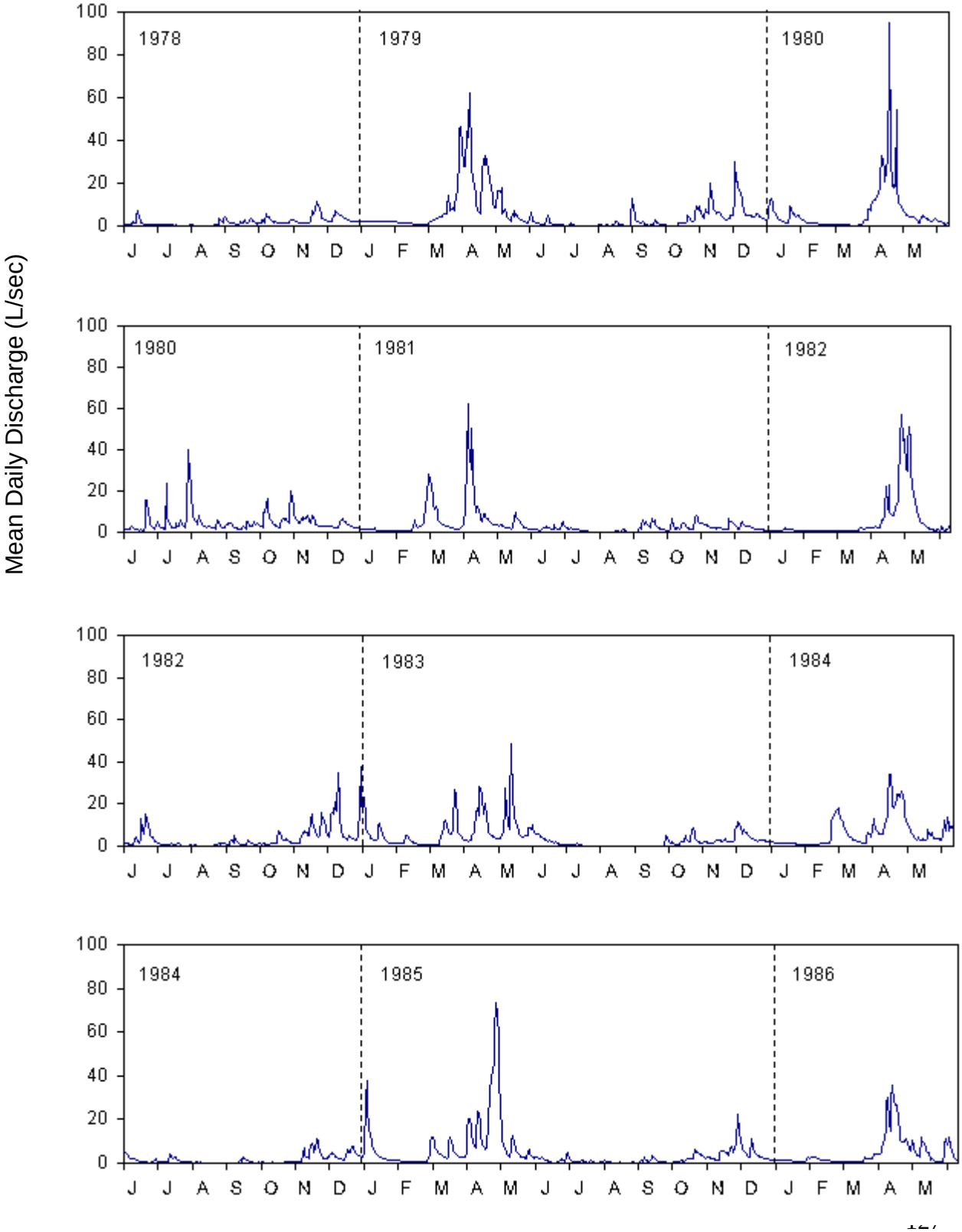



80
60
40
20
0
2006
2007
J J A S O N D J F M A M

Dickie Inflow 6 Hydrograph



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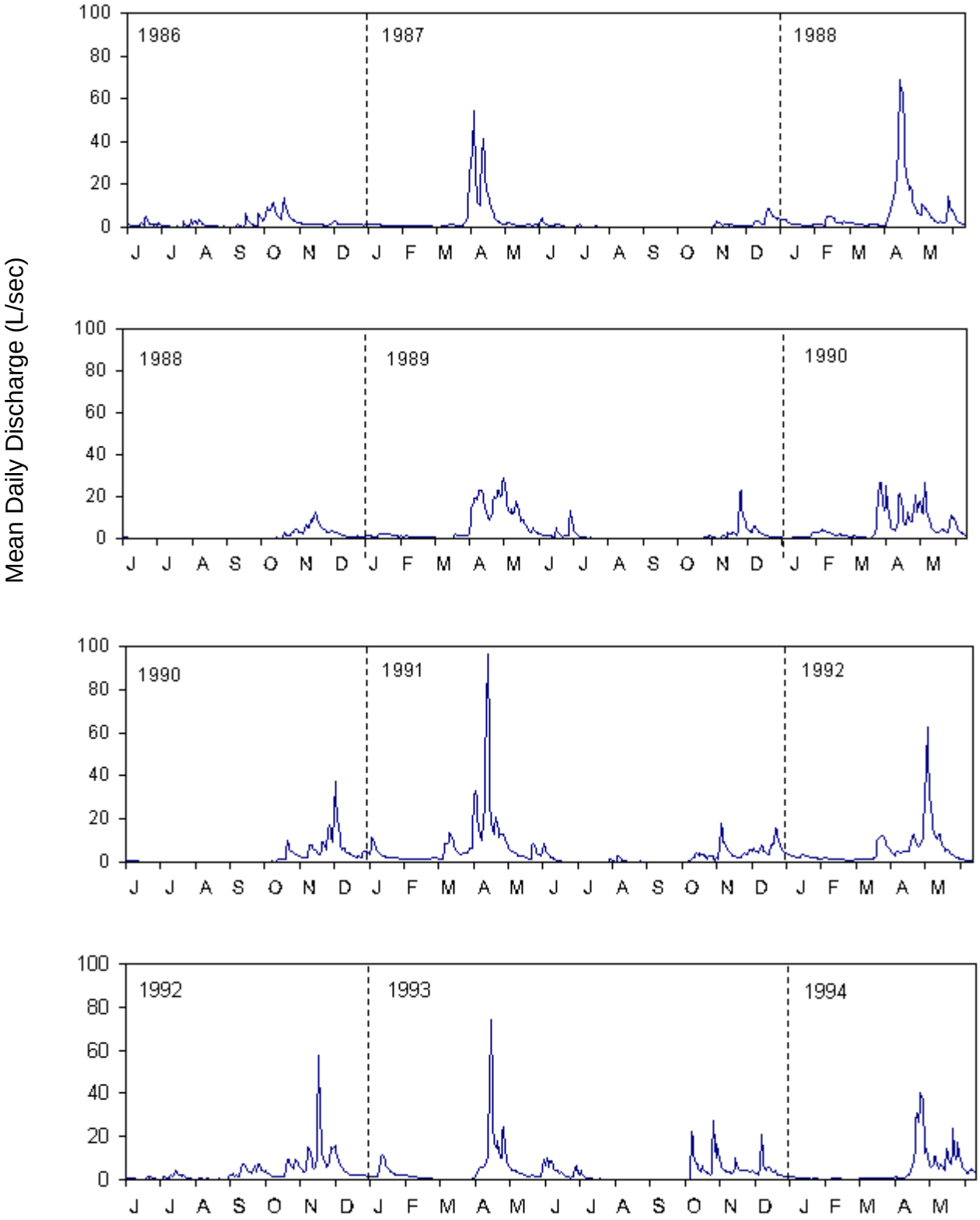

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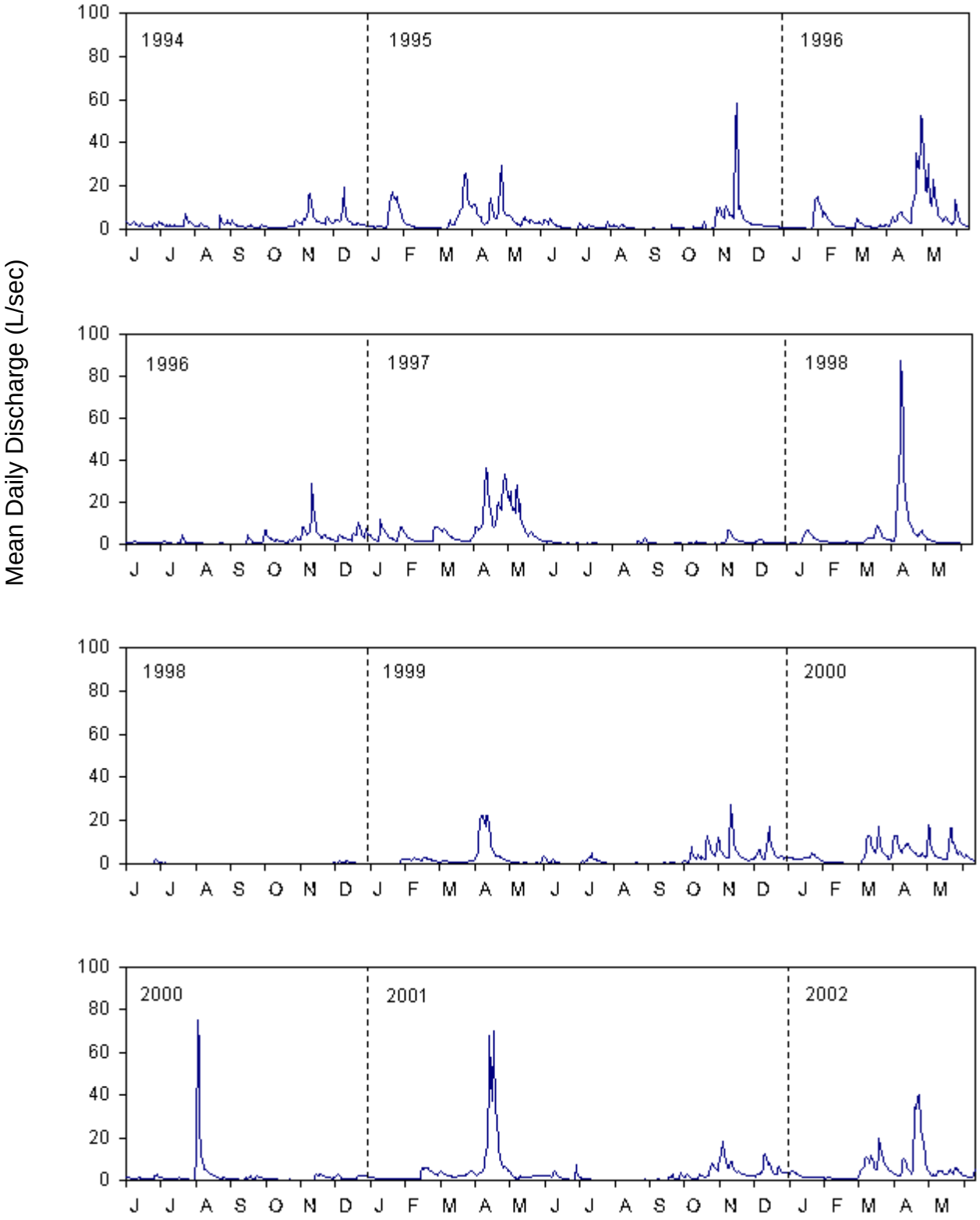

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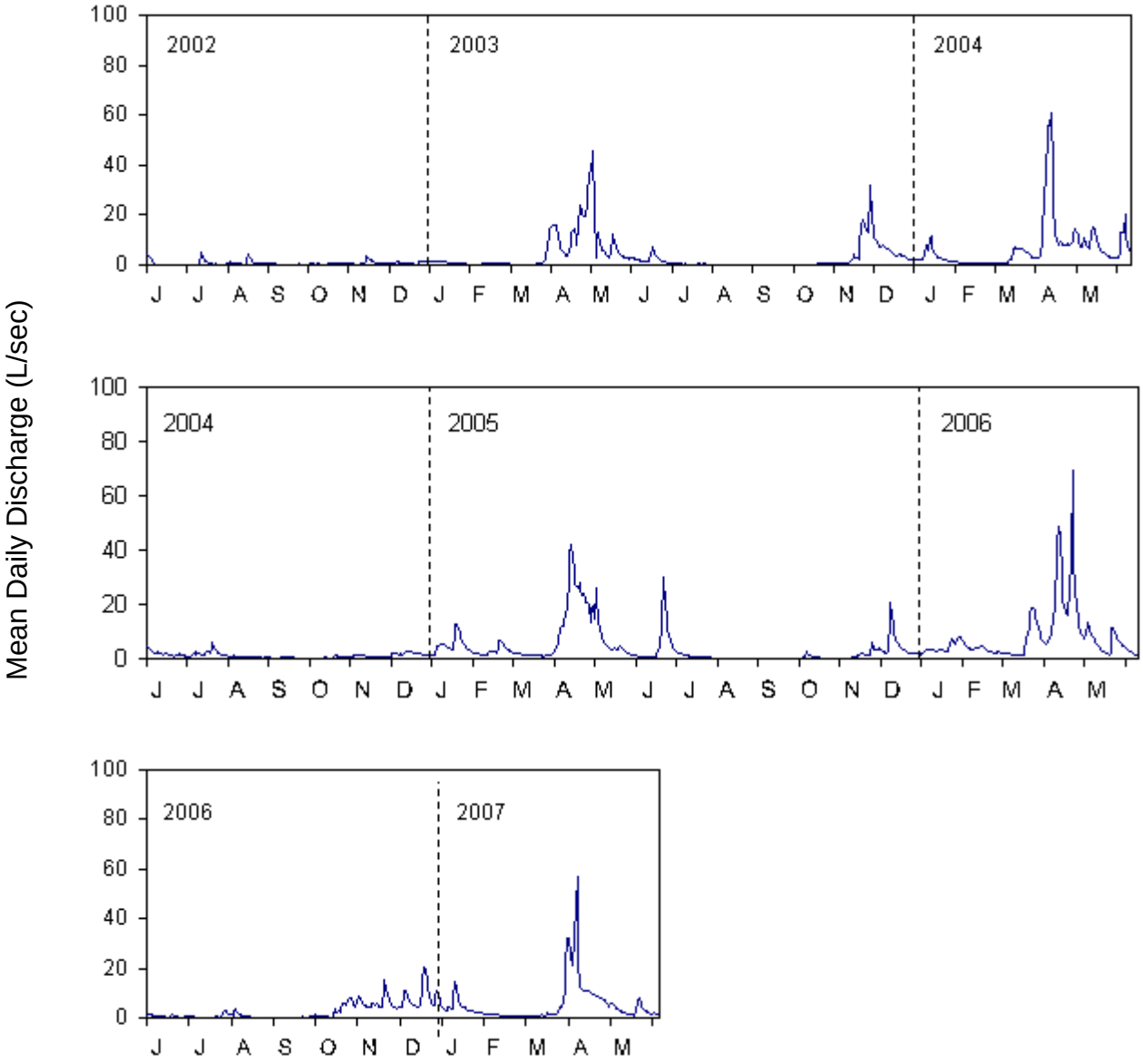

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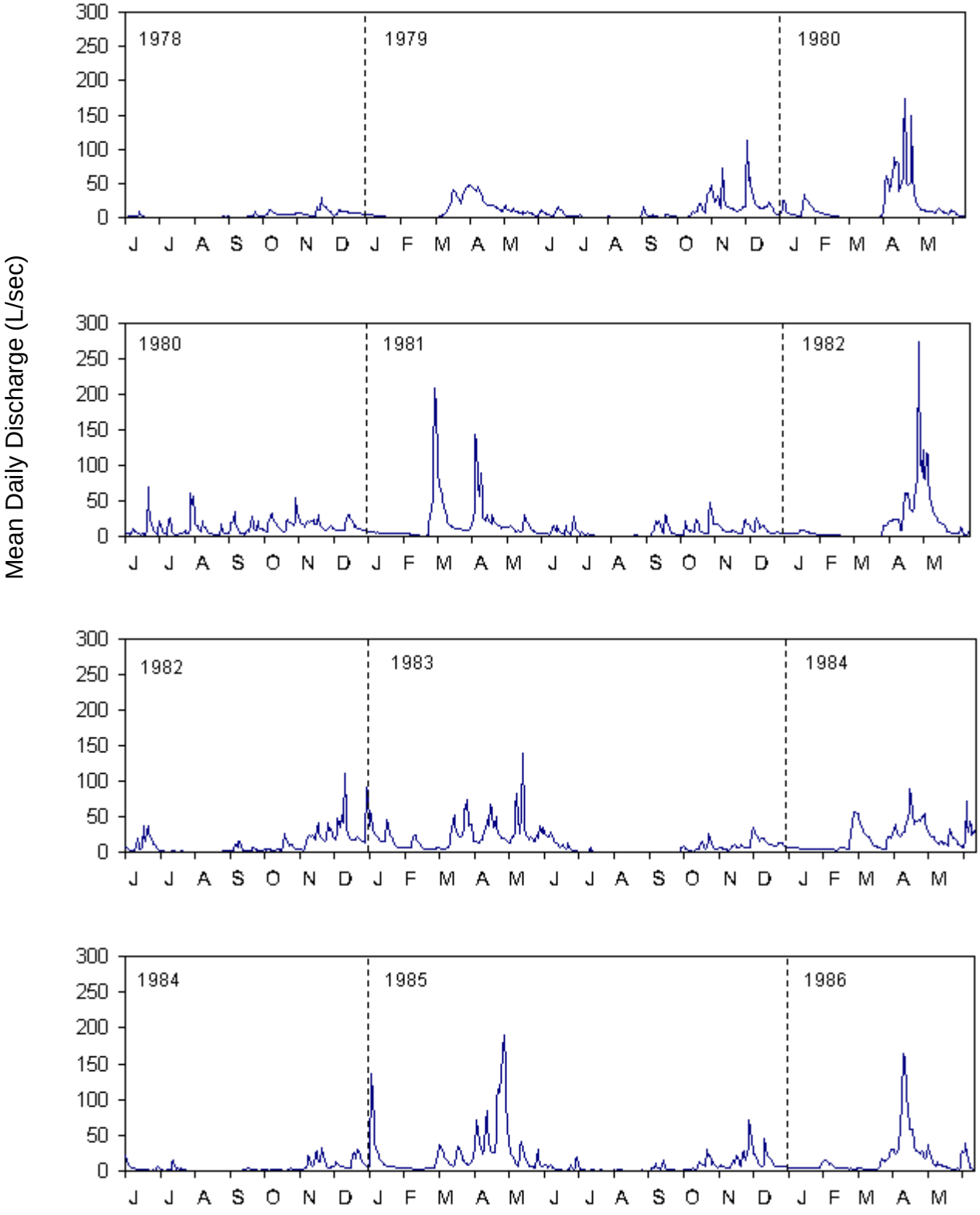

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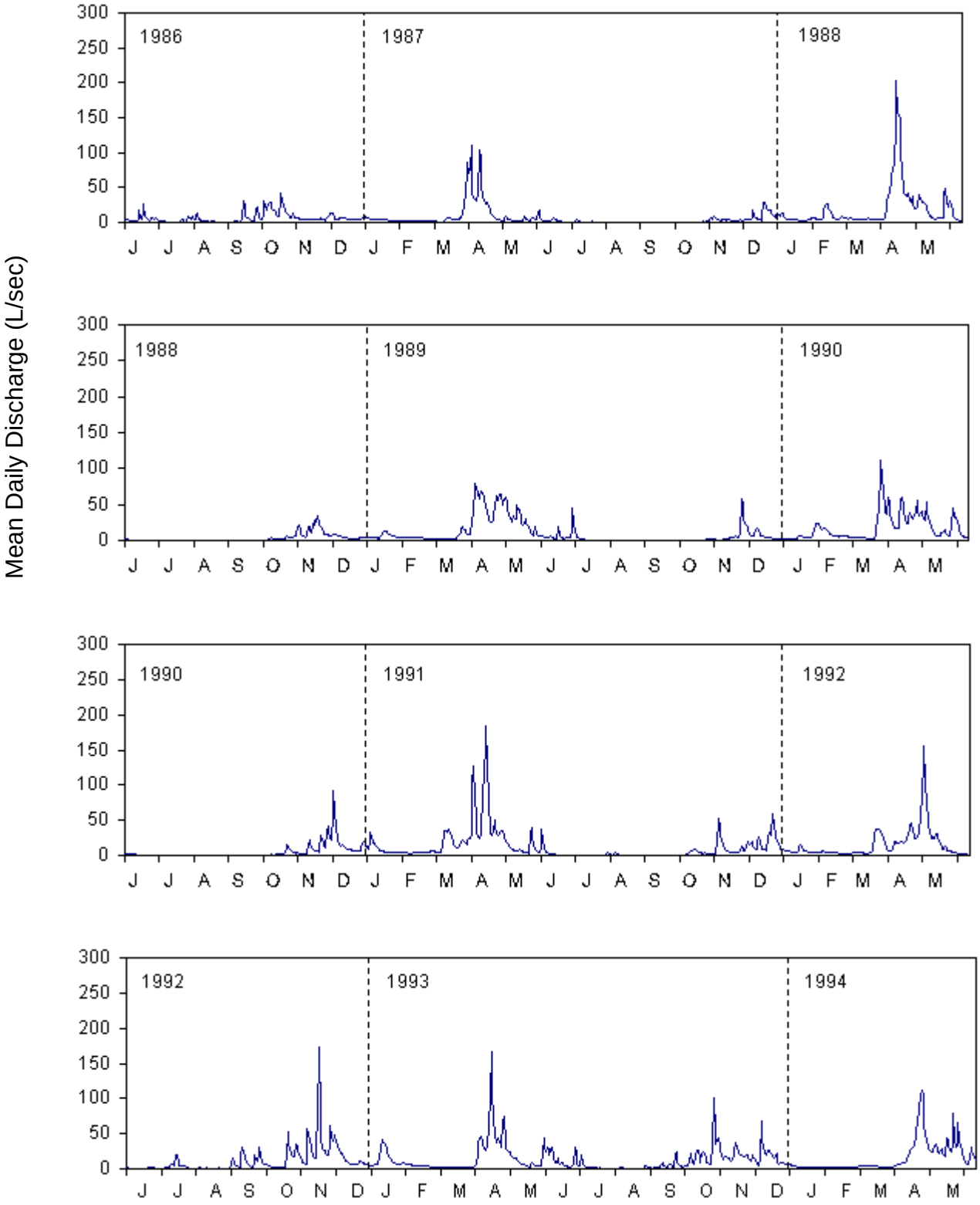

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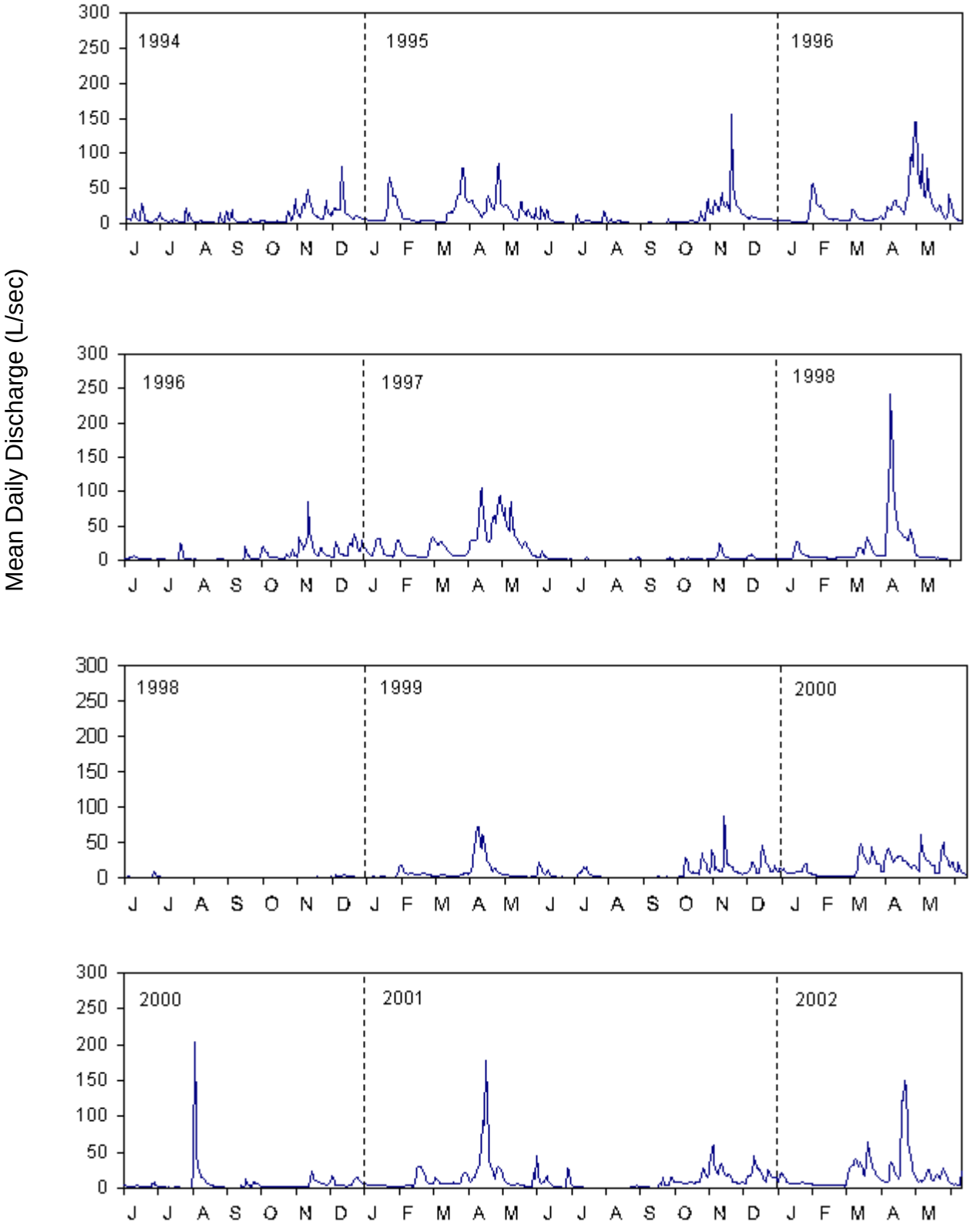

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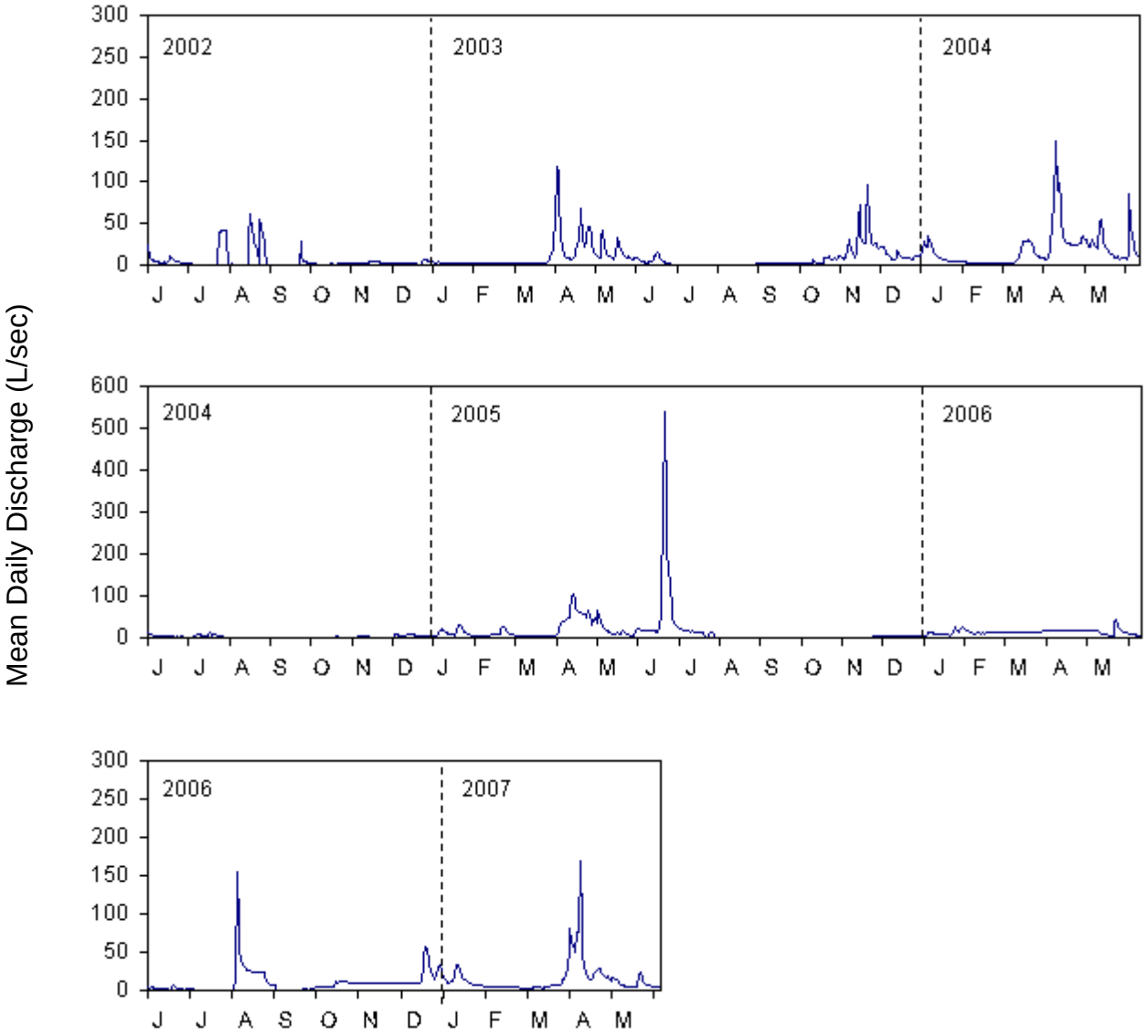

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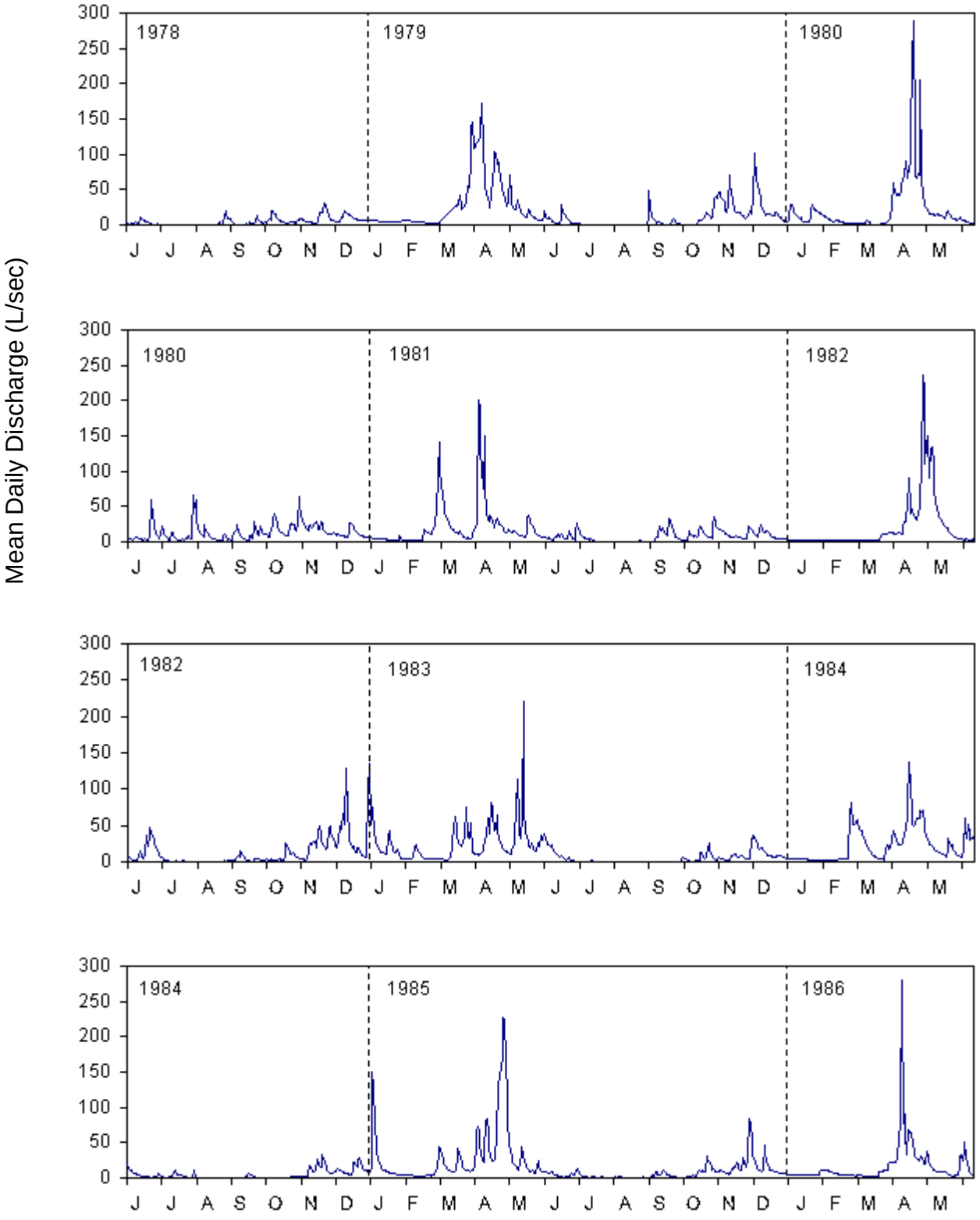

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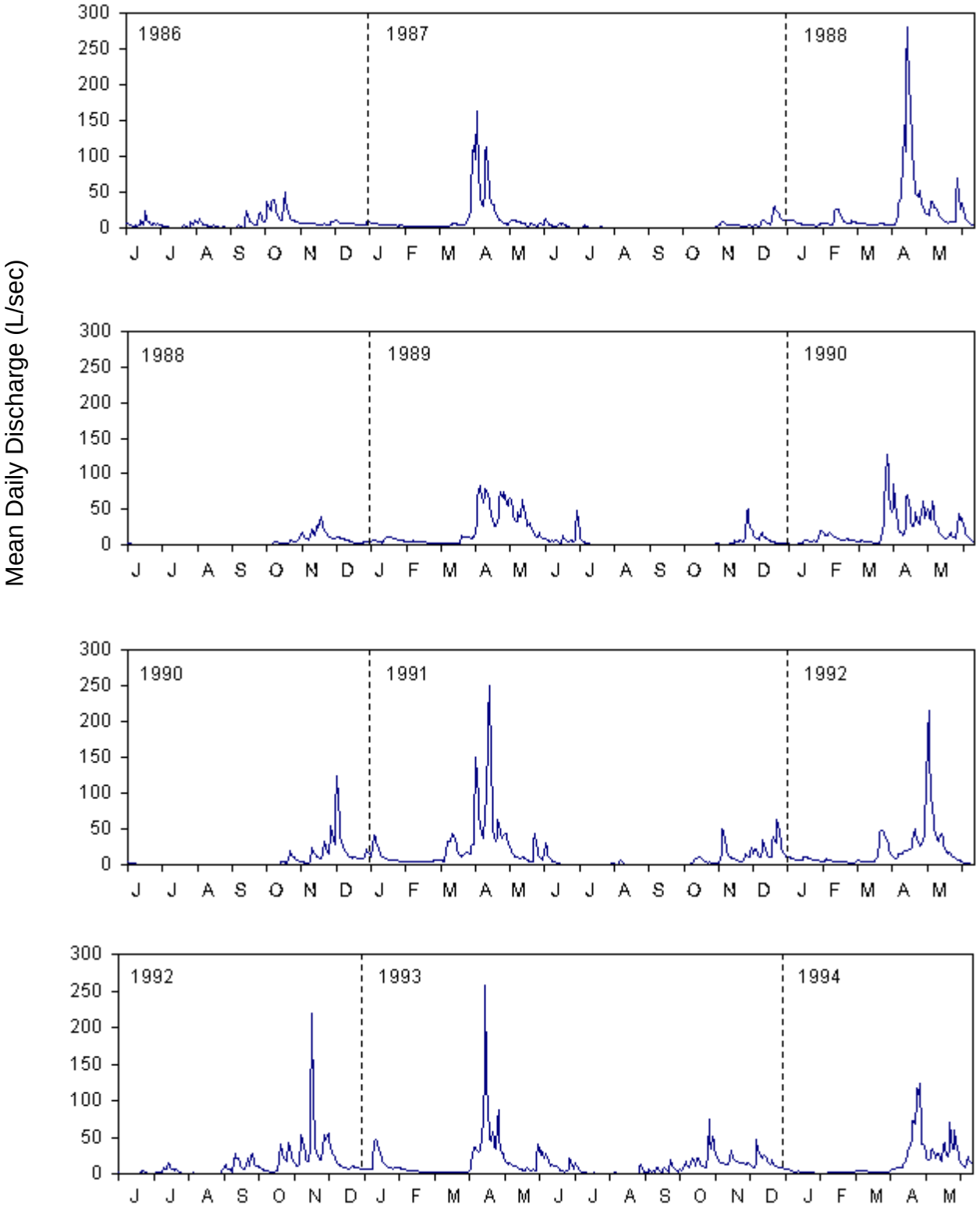

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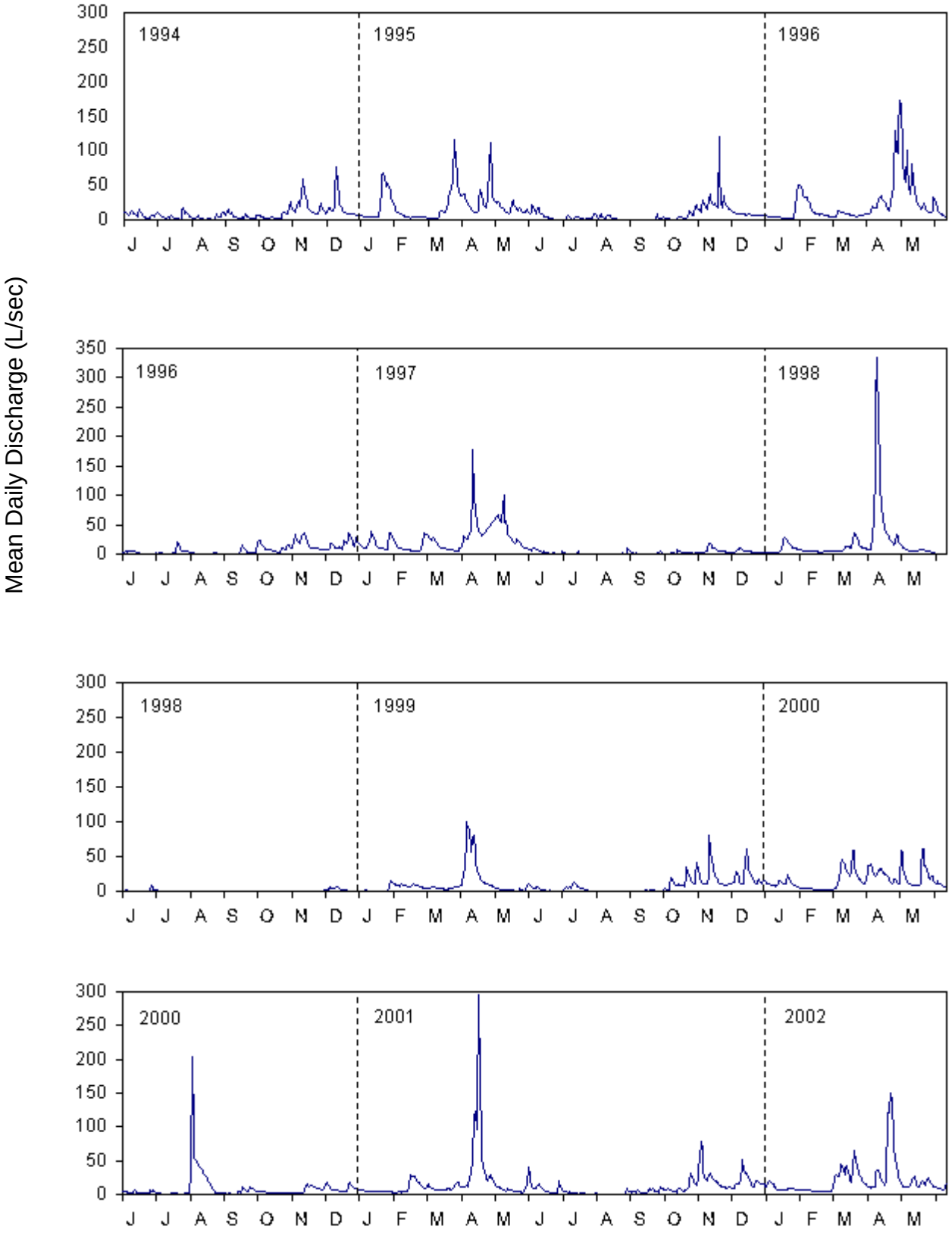

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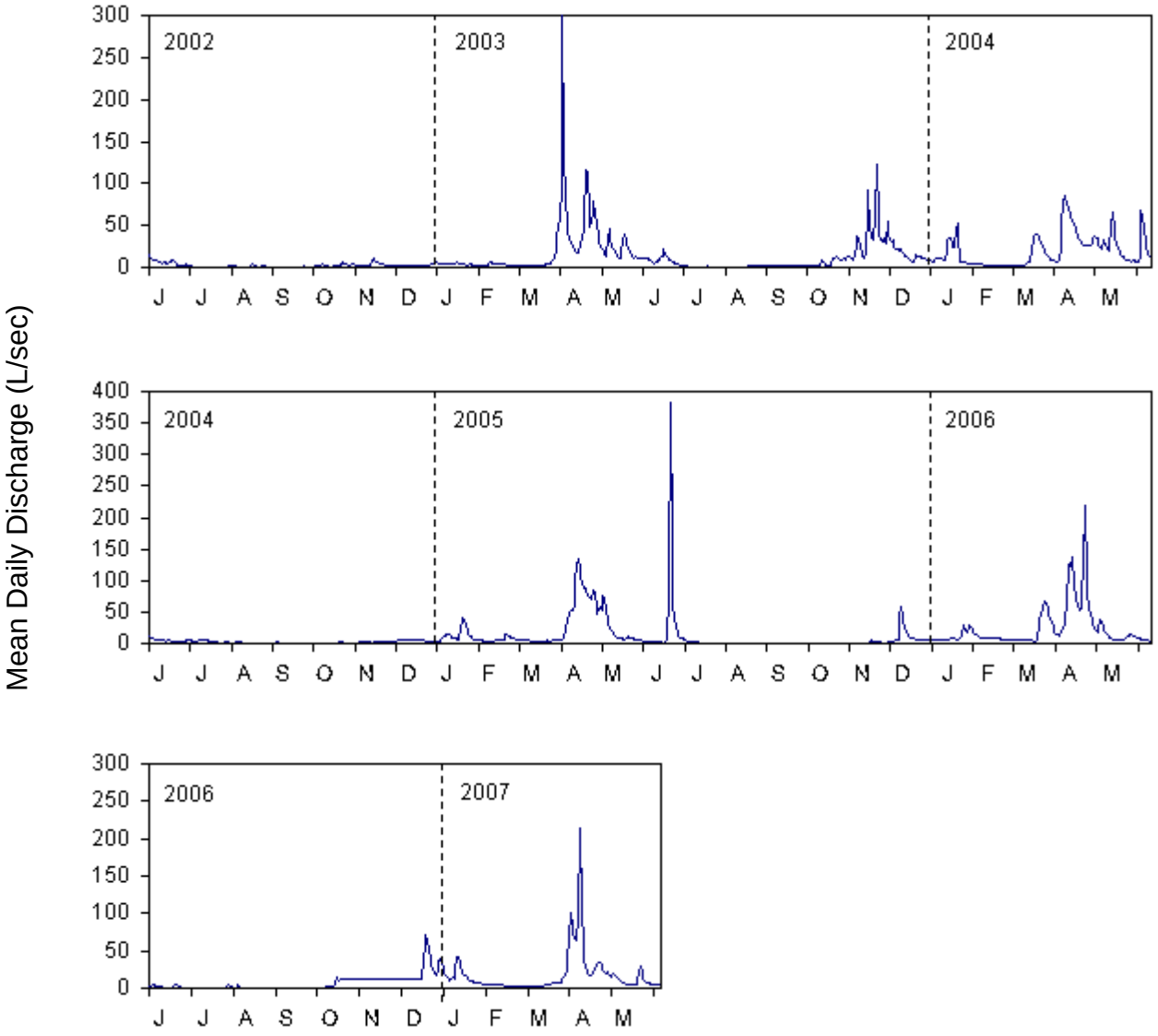
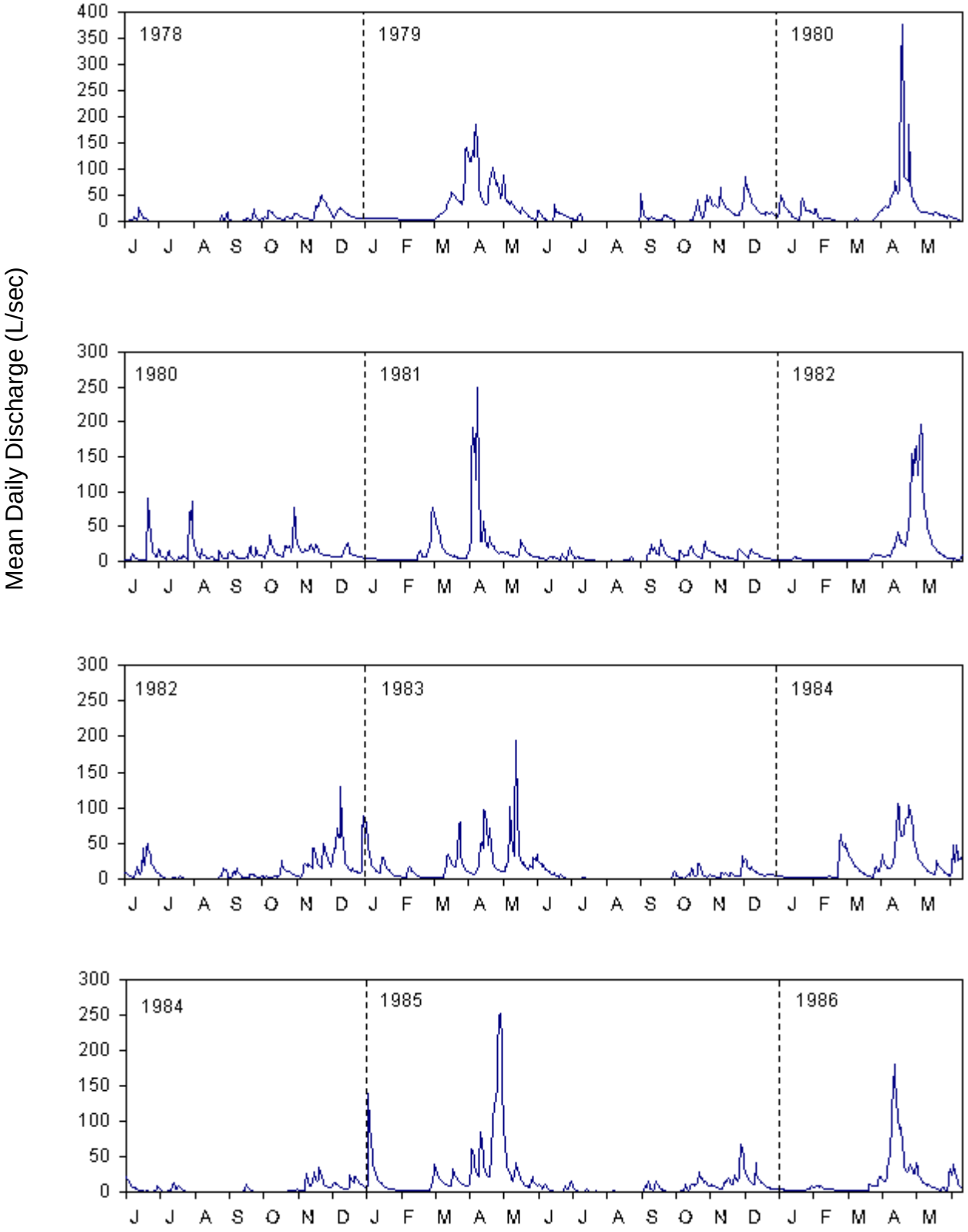
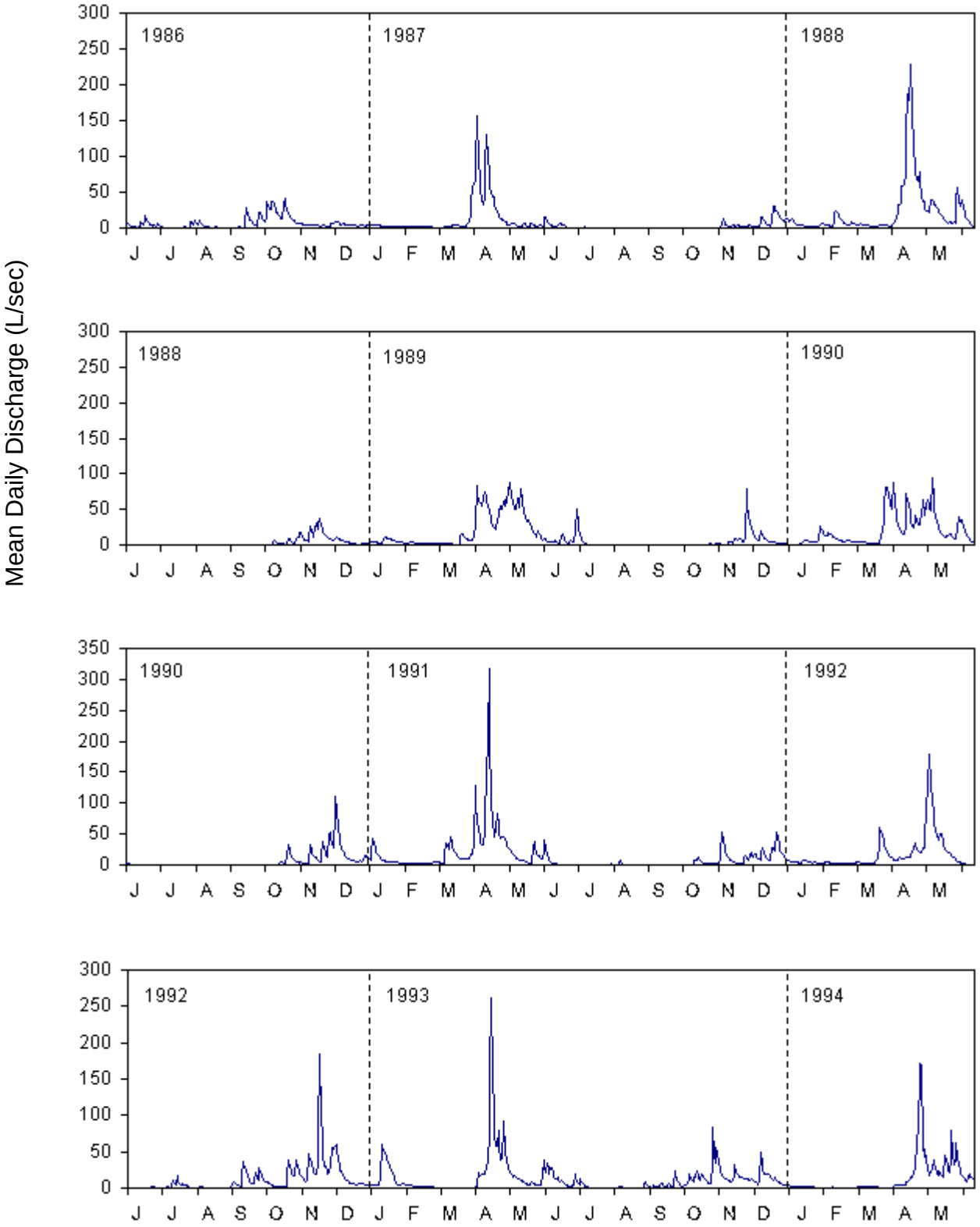


Dickie Inflow 11 Hydrograph



Dickie Inflow 11 Hydrograph



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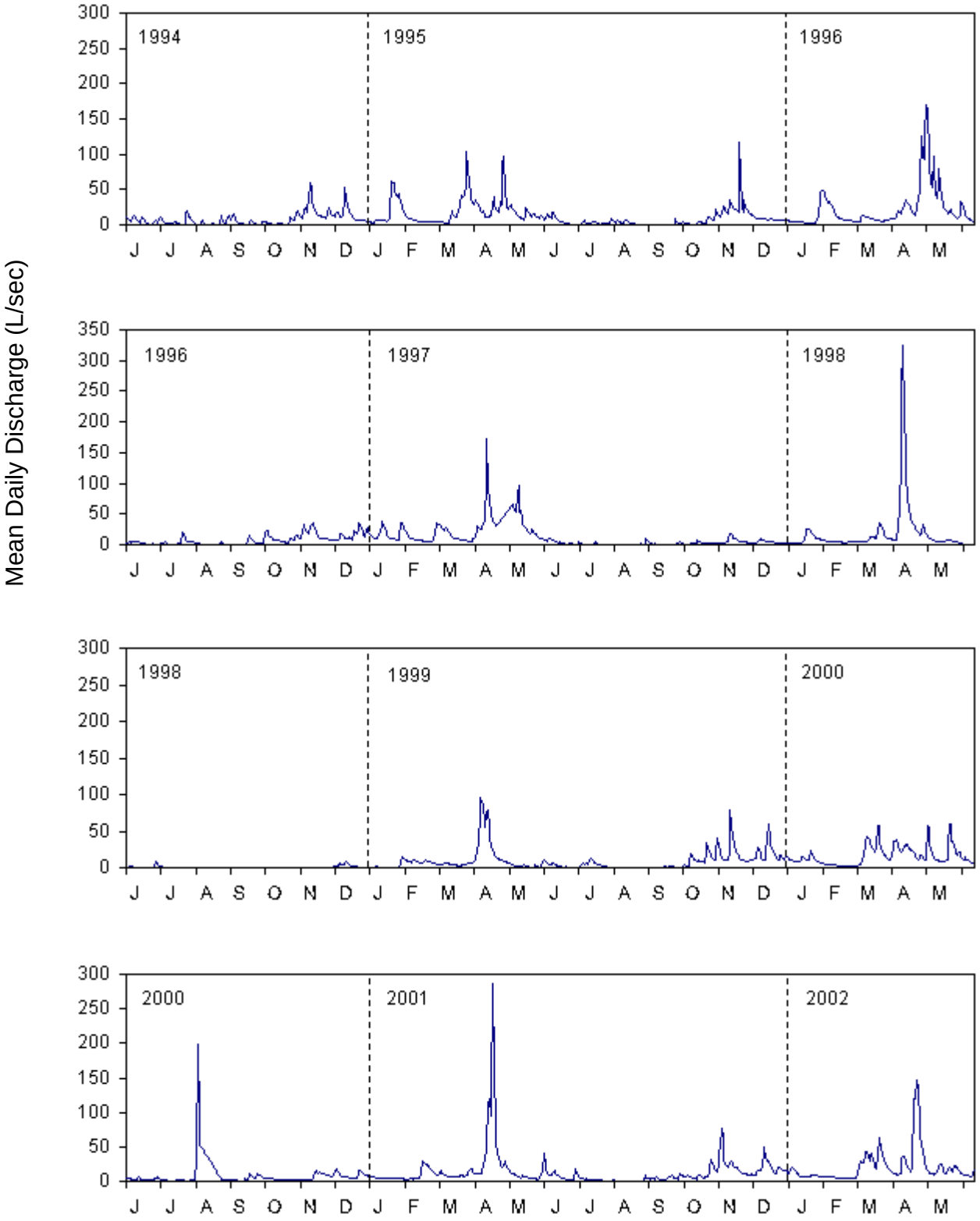

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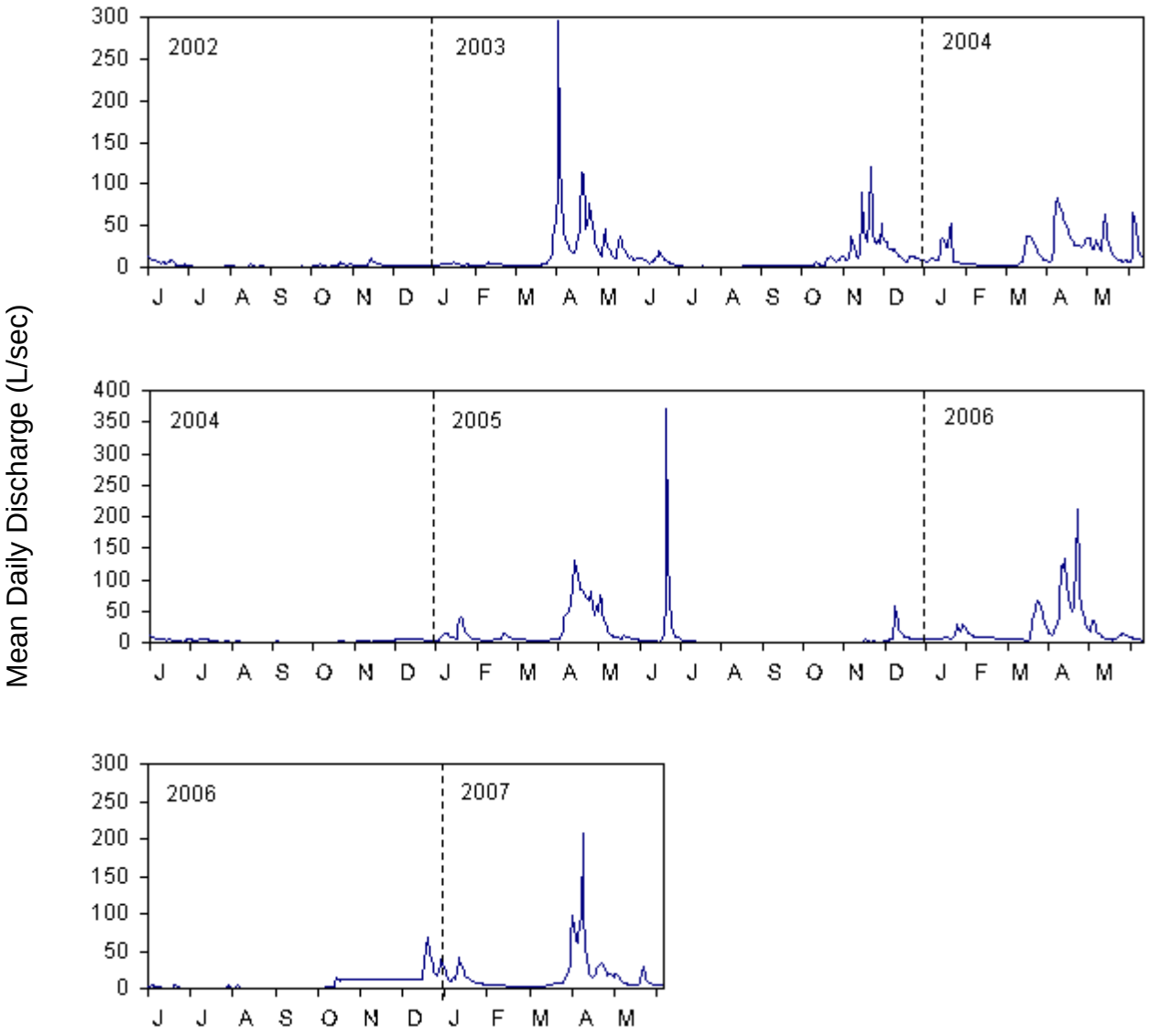
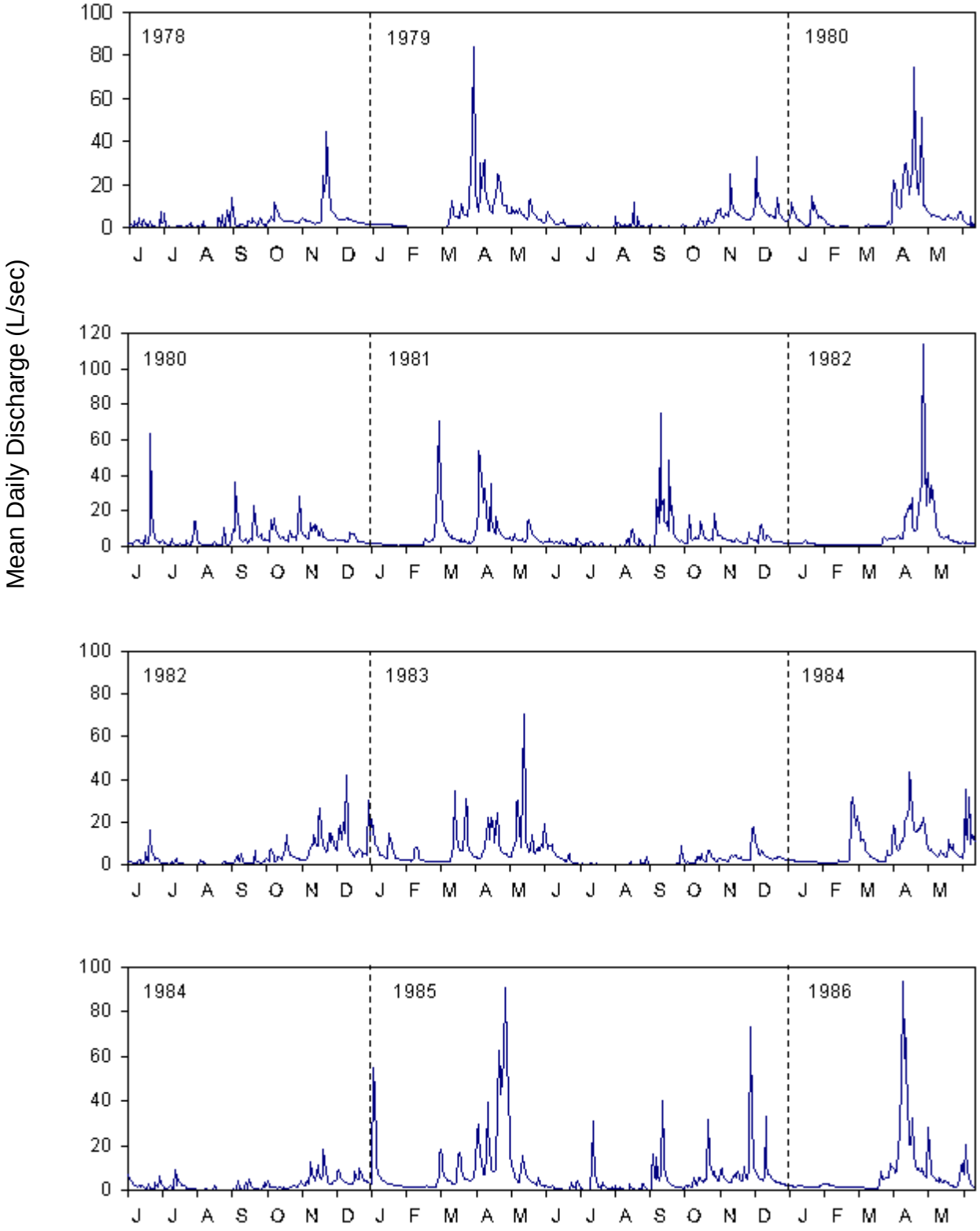
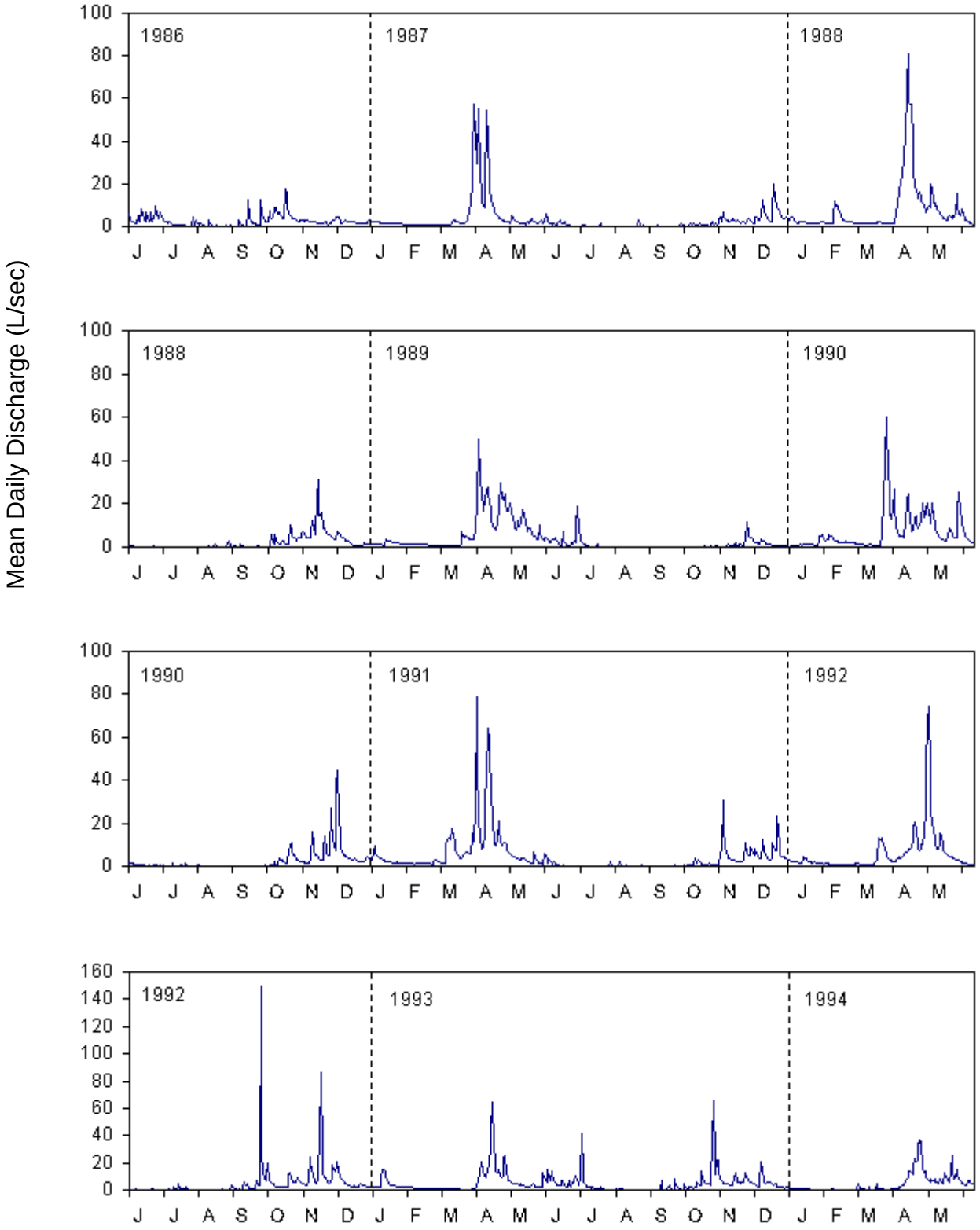


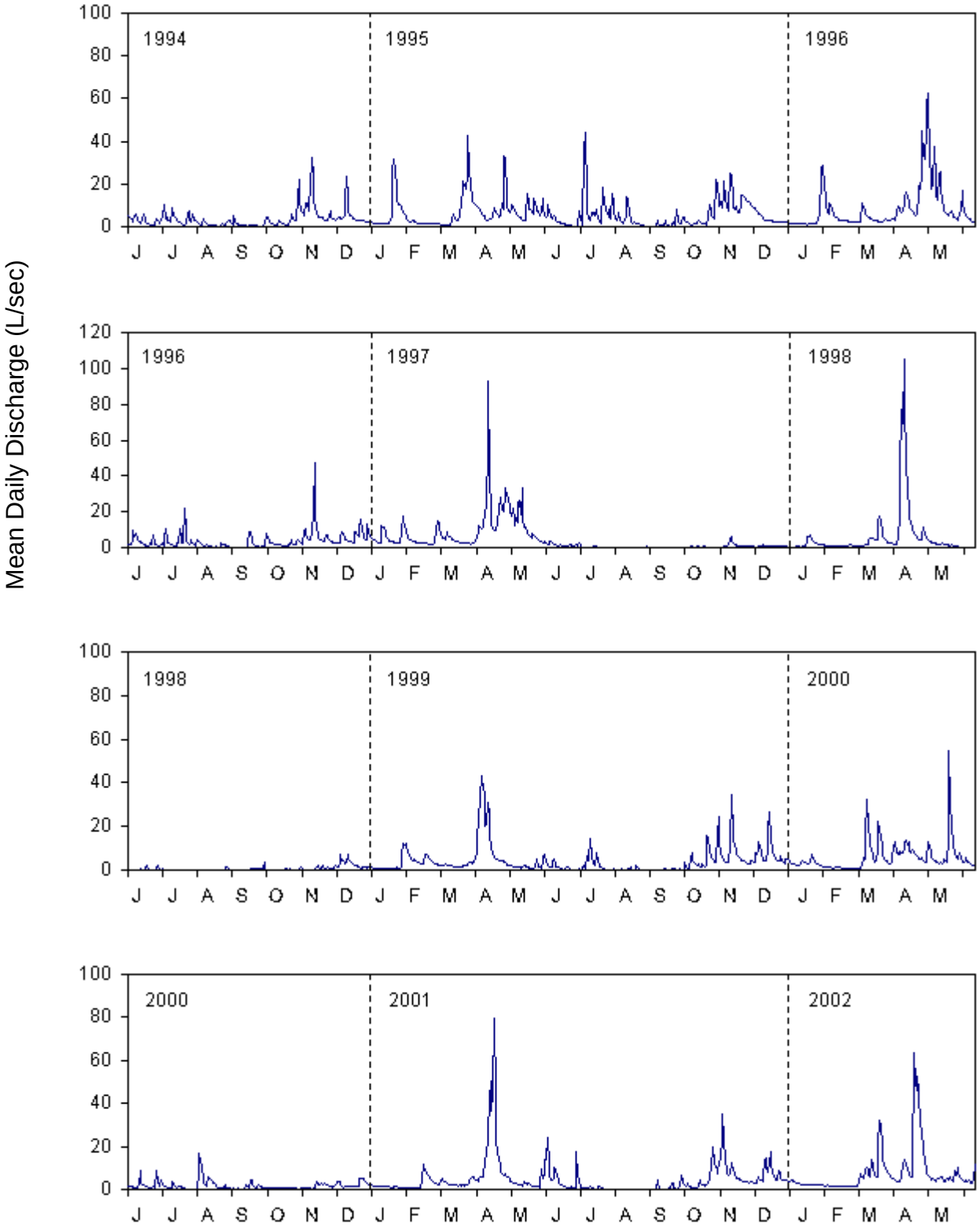
Harp Inflow 3 Hydrograph



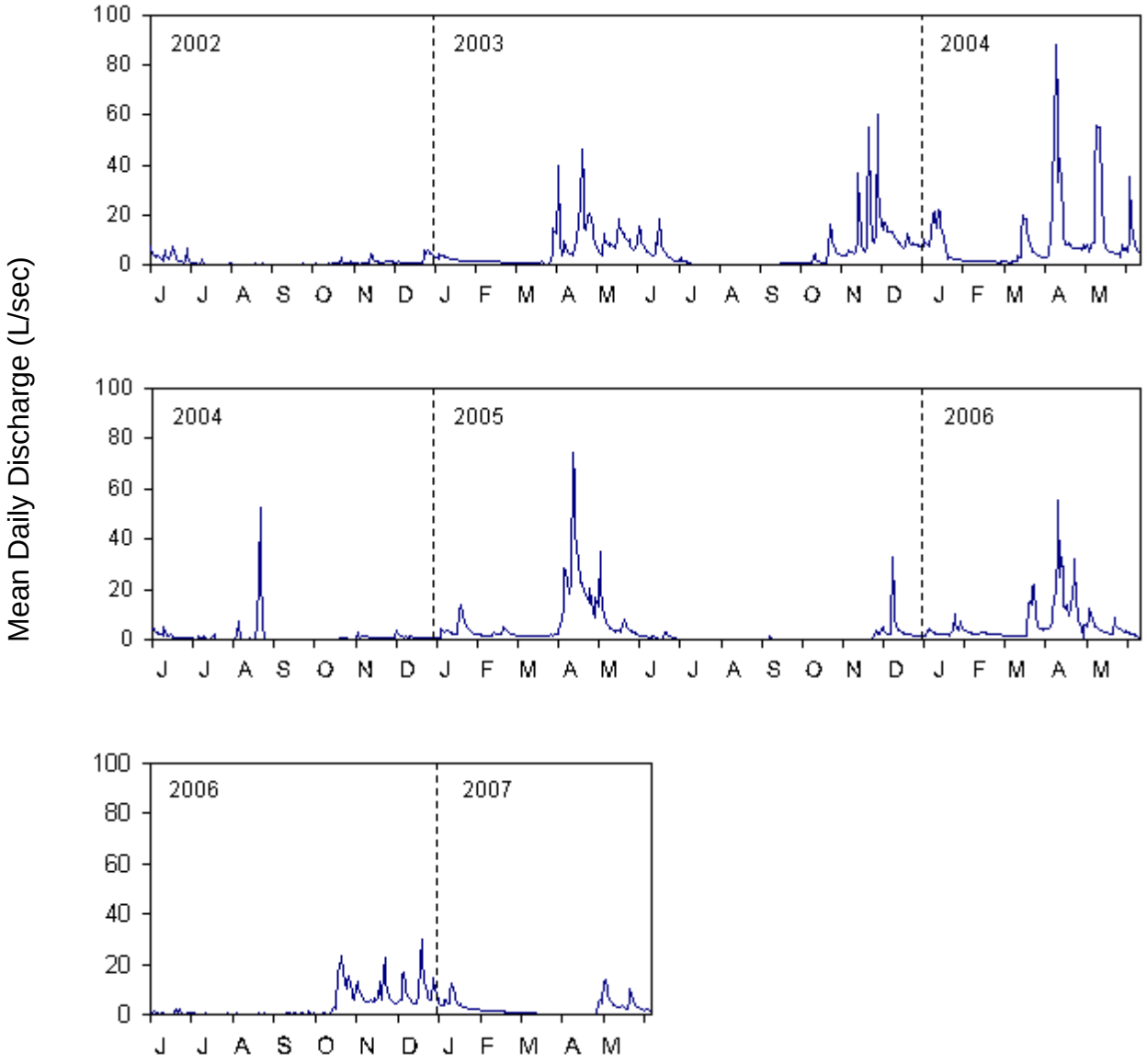
Harp Inflow 3 Hydrograph



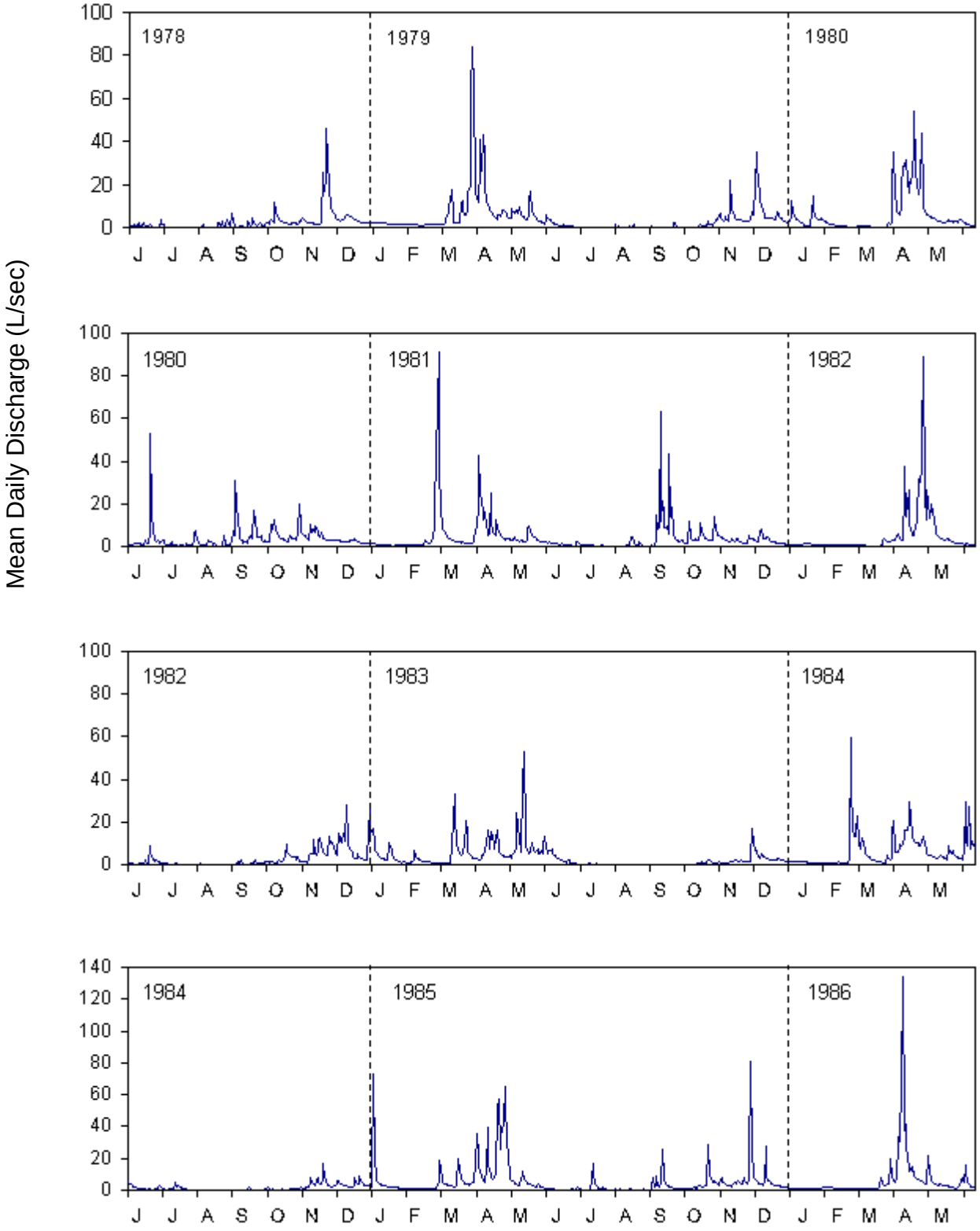
Harp Inflow 3 Hydrograph



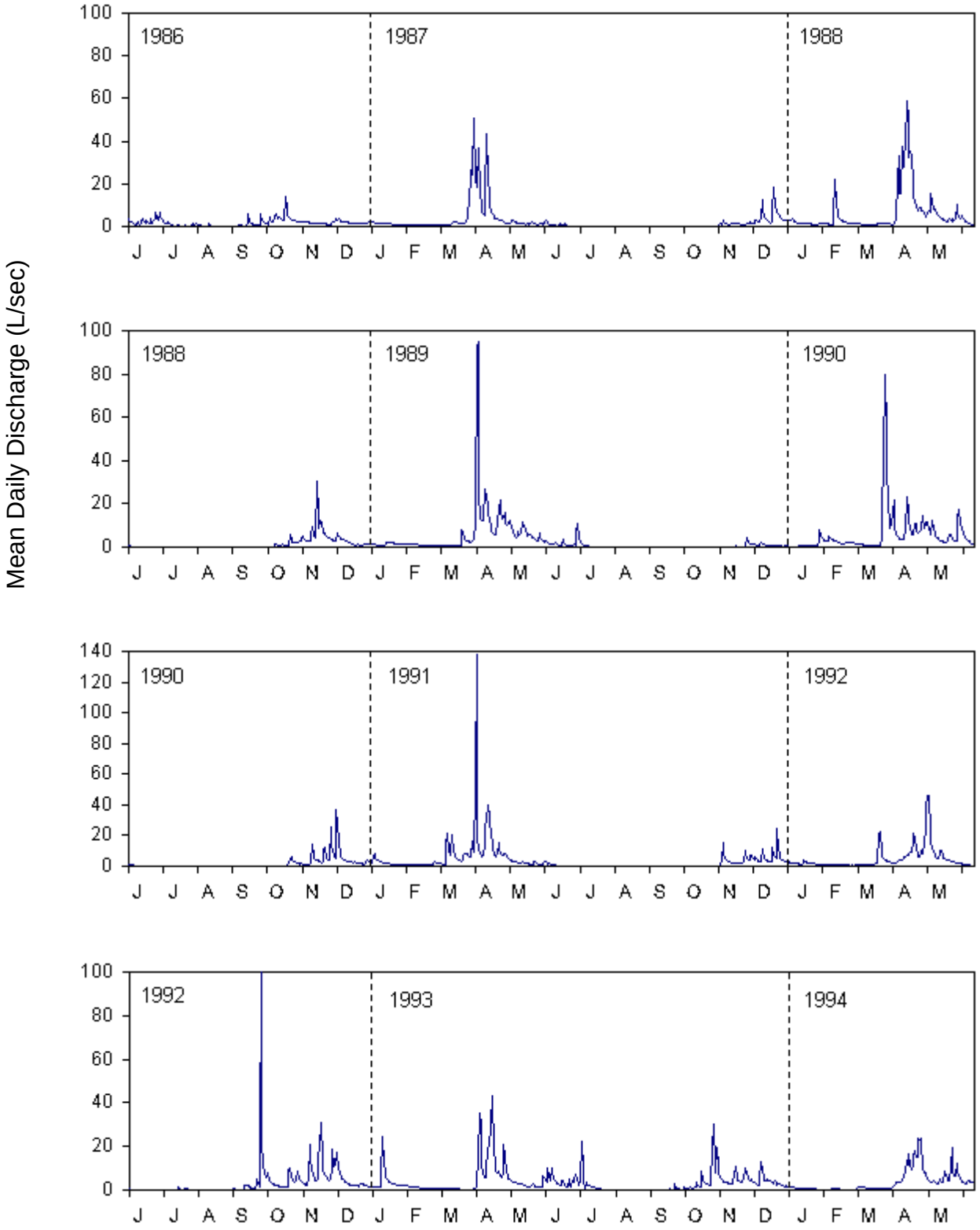
Harp Inflow 3 Hydrograph



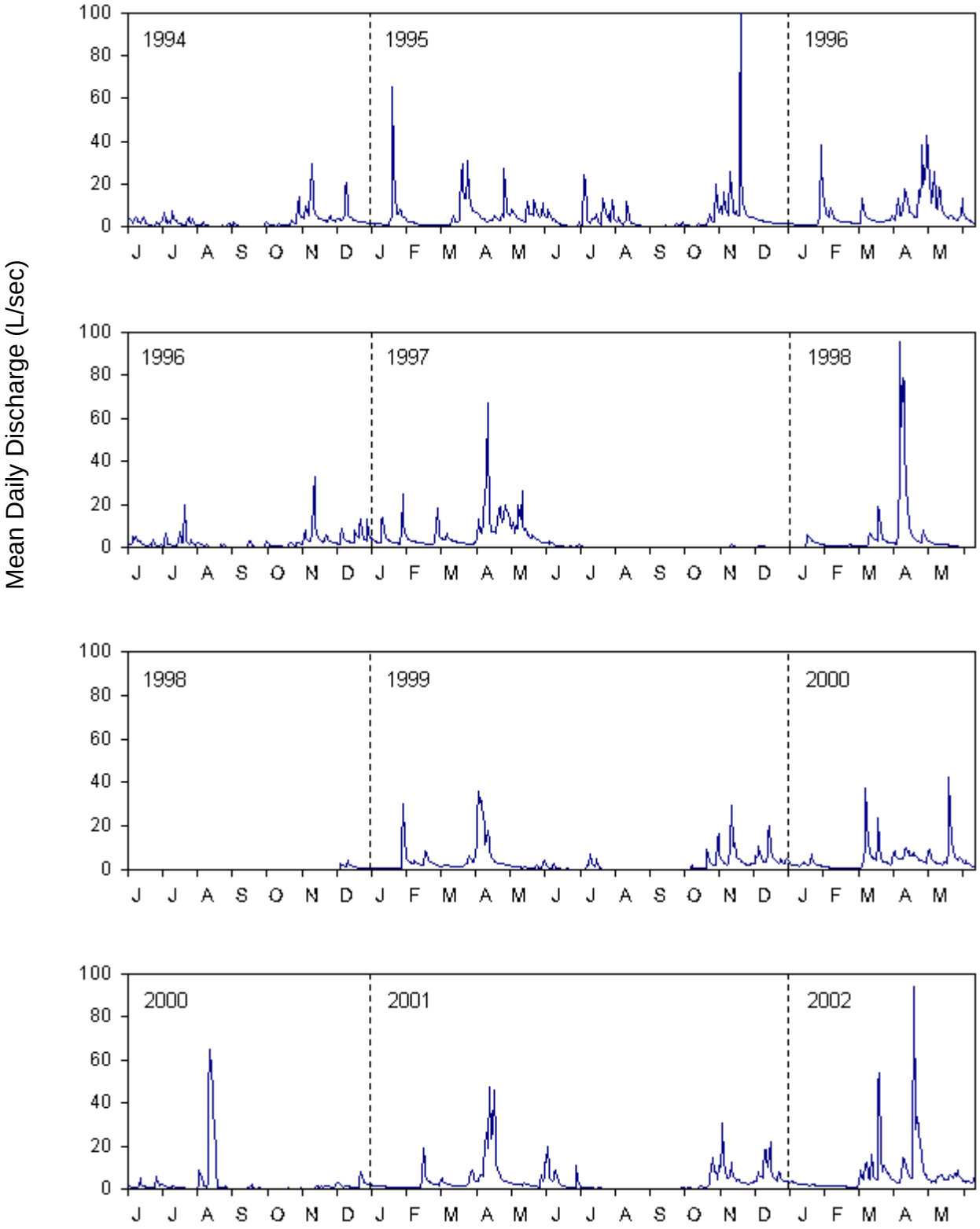
Harp Inflow 3a Hydrograph



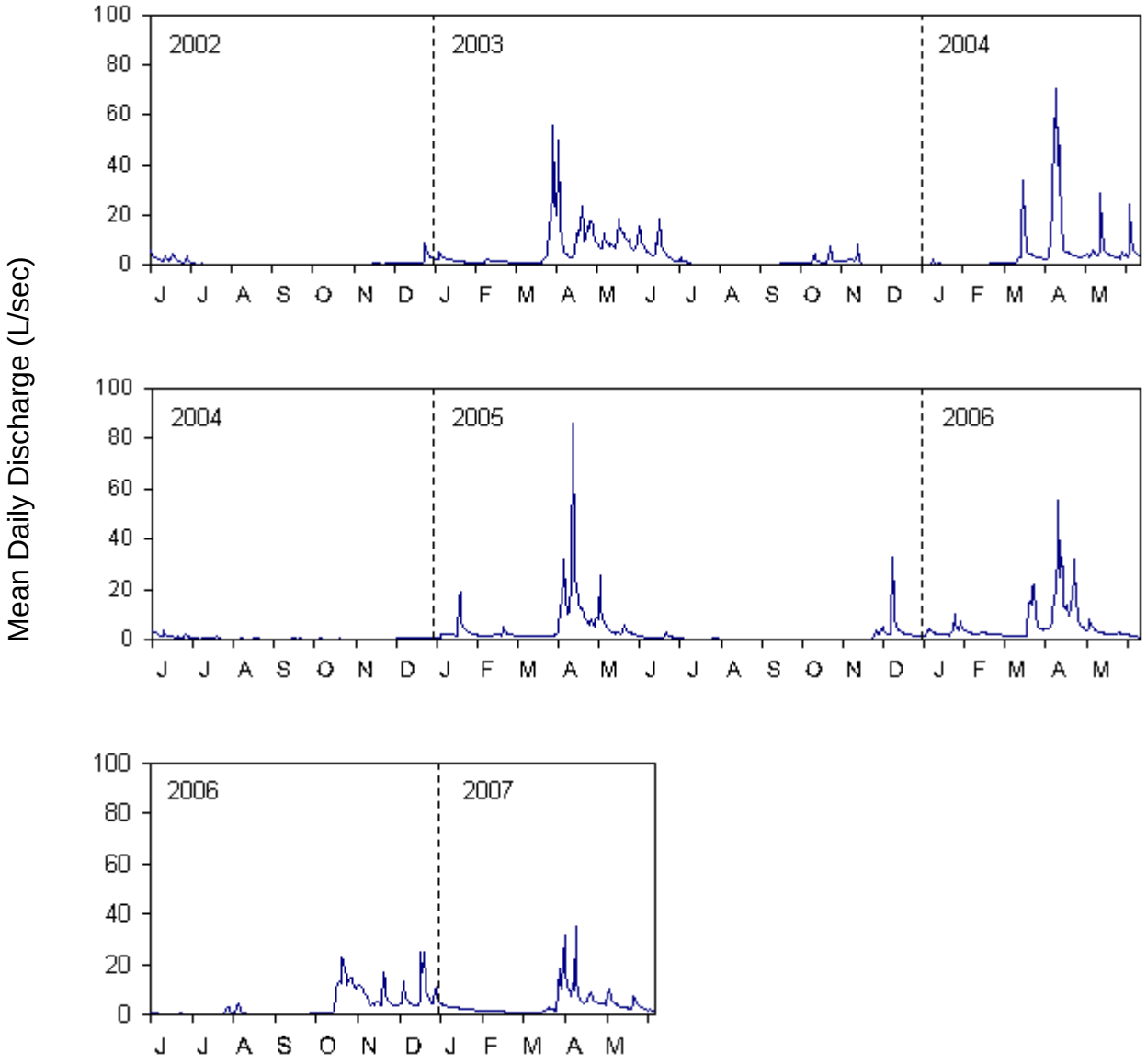
Harp Inflow 3a Hydrograph



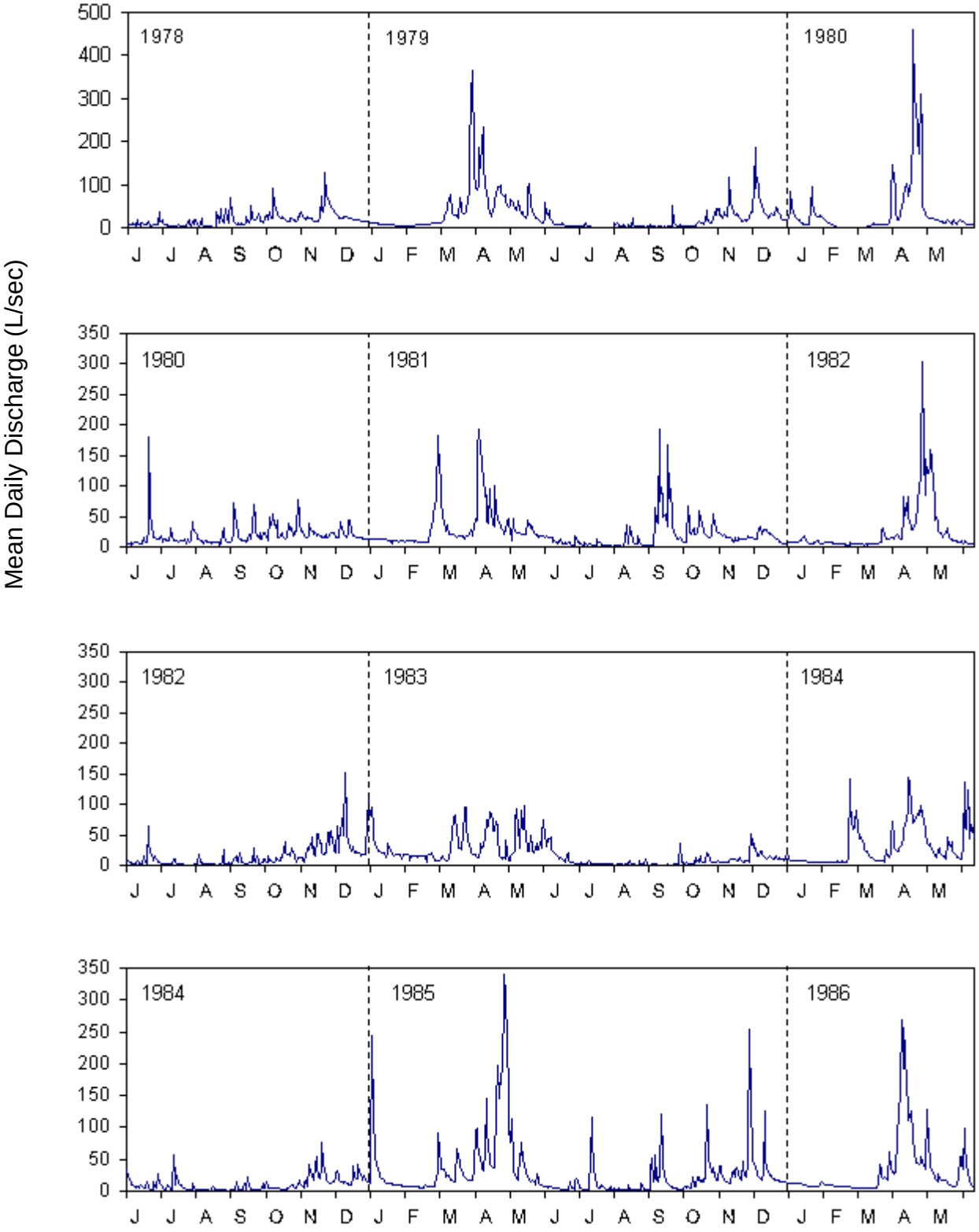
Harp Inflow 3a Hydrograph



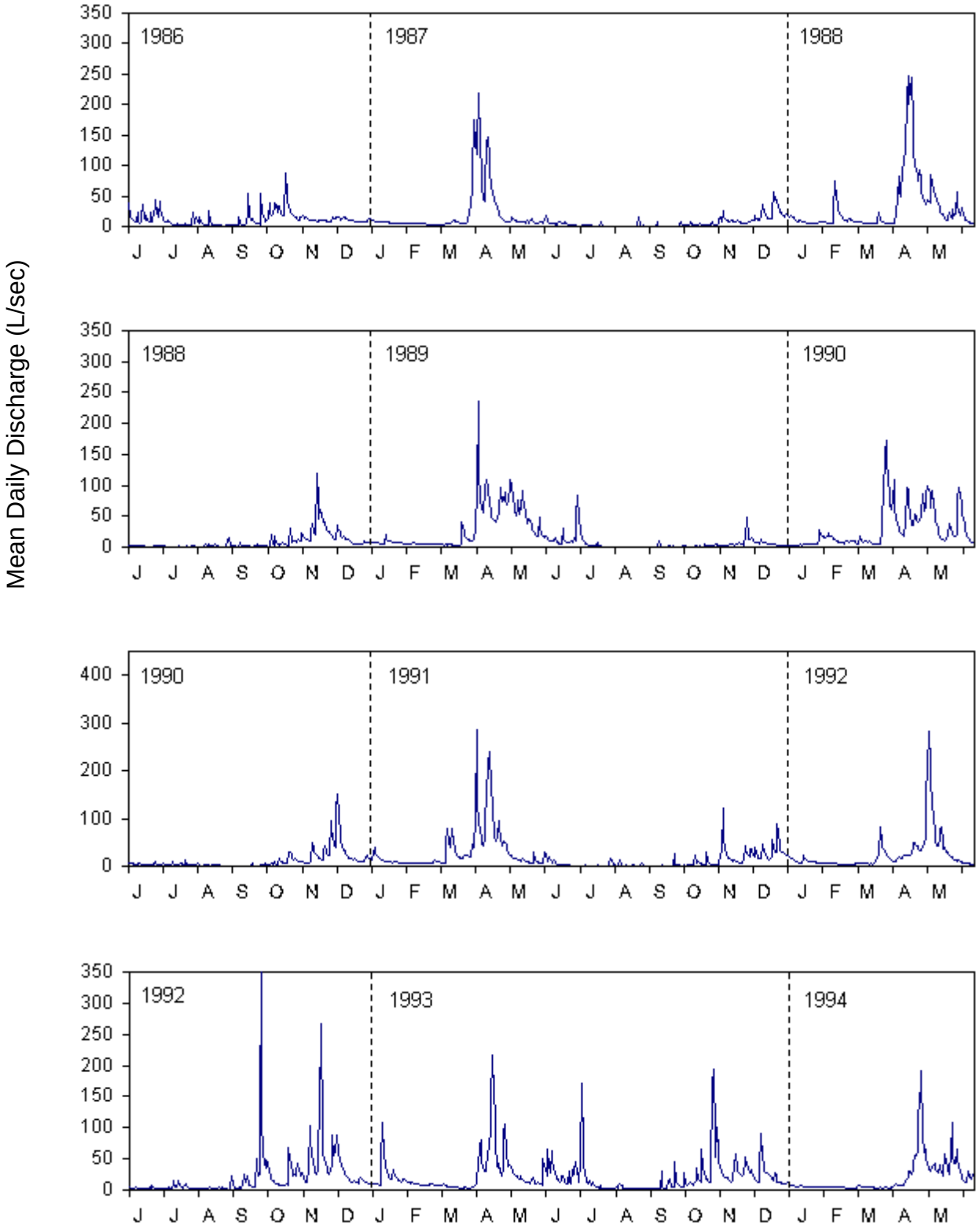
Harp Inflow 3a Hydrograph


Mean Daily Discharge (L/sec)
100
80
60
40
20
0
2002
2003
2004
J J A S O N D J F M A M J J A S O N D J F M A M
2004
2005
2006
J J A S O N D J F M A M J J A S O N D J F M A M
2006
2007
J J A S O N D J F M A M

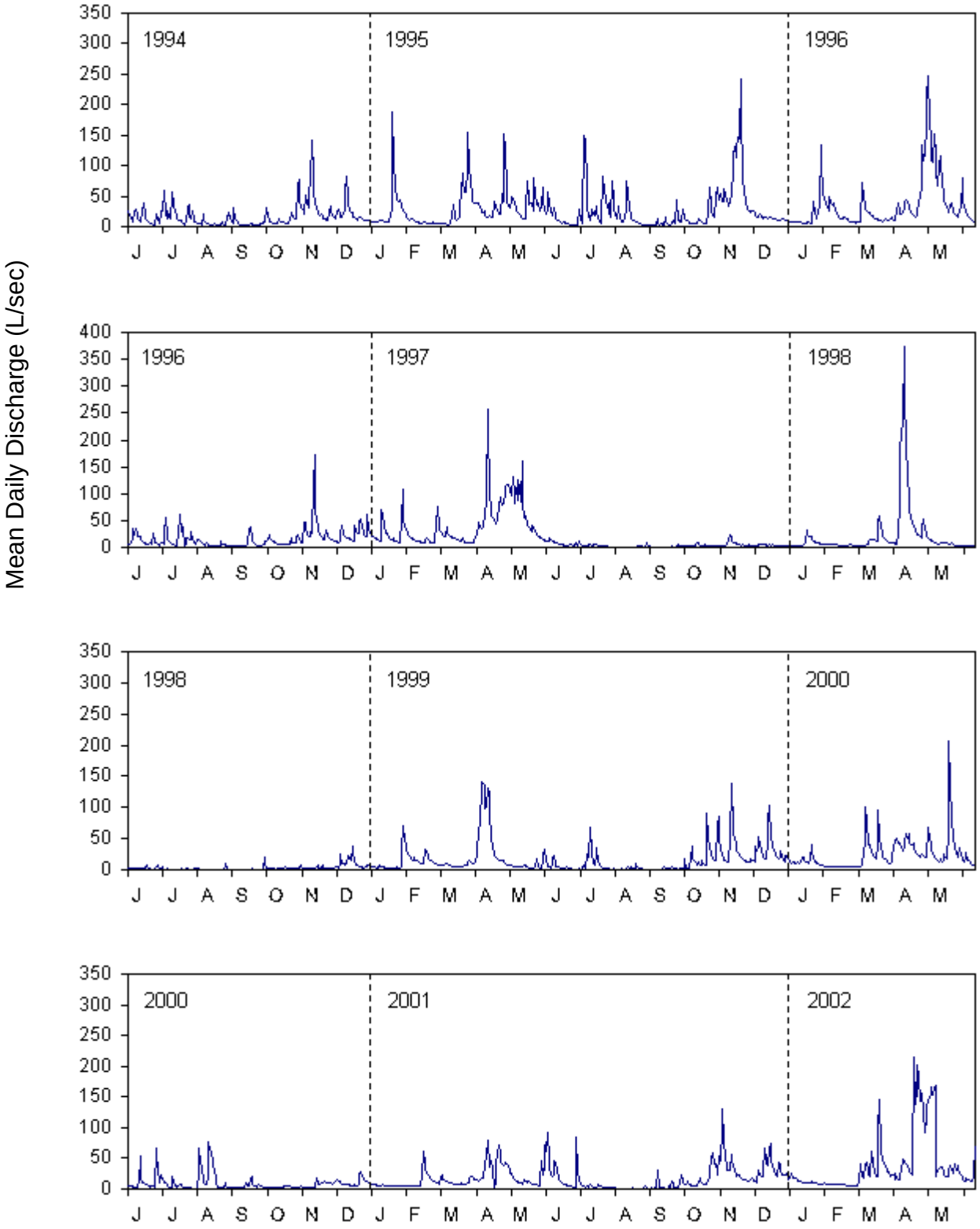
Harp Inflow 4 Hydrograph



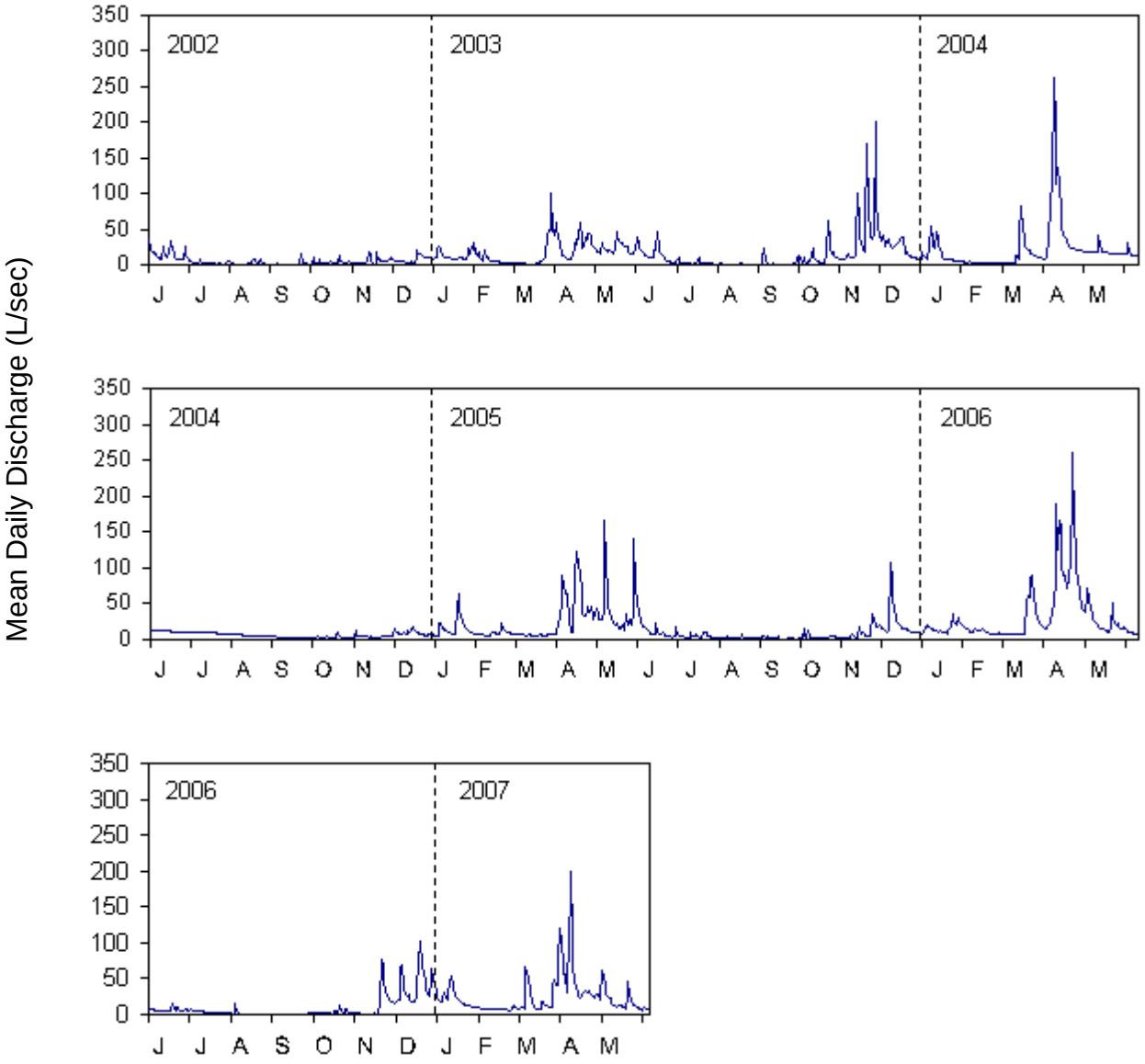
Harp Inflow 4 Hydrograph



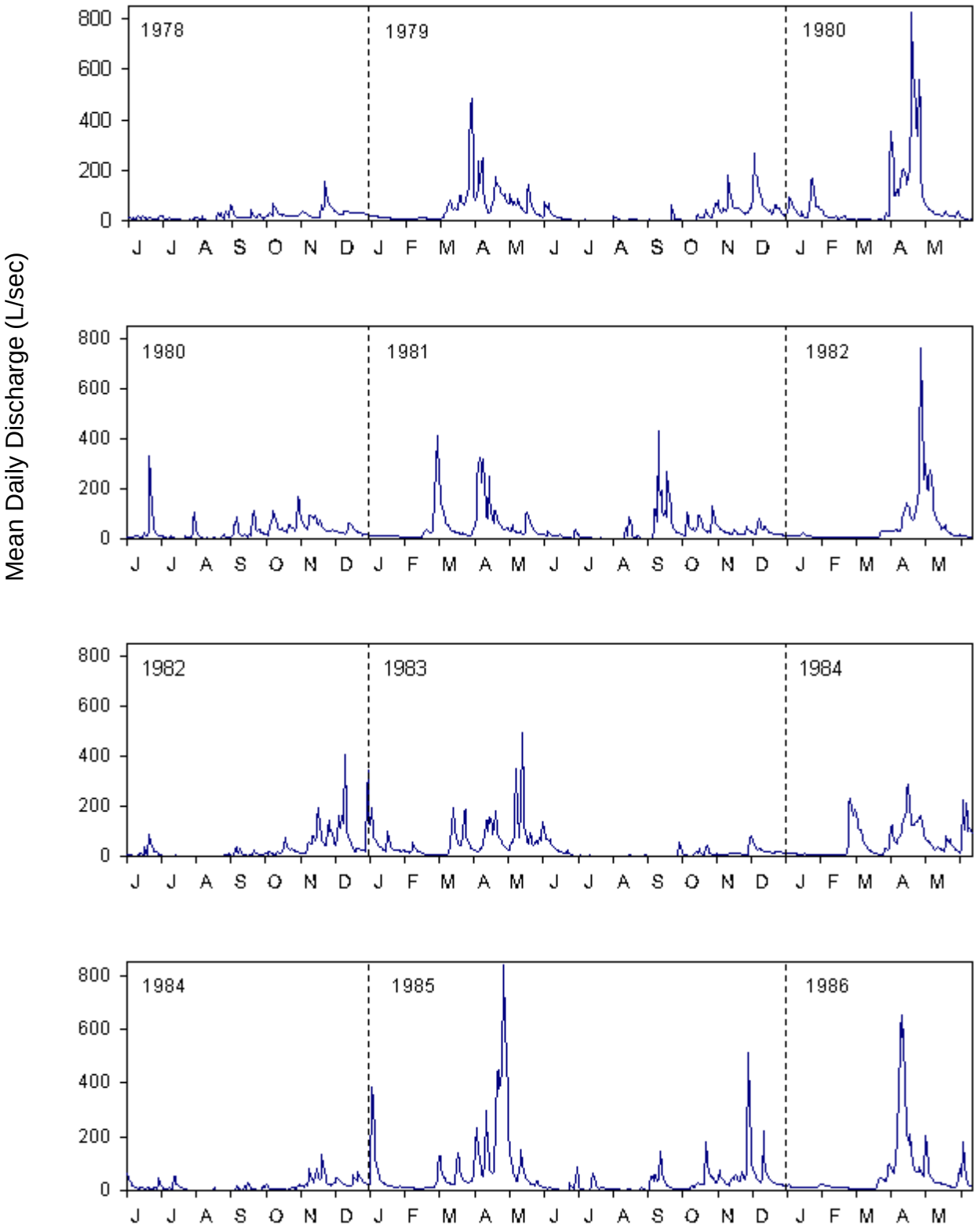
Harp Inflow 4 Hydrograph



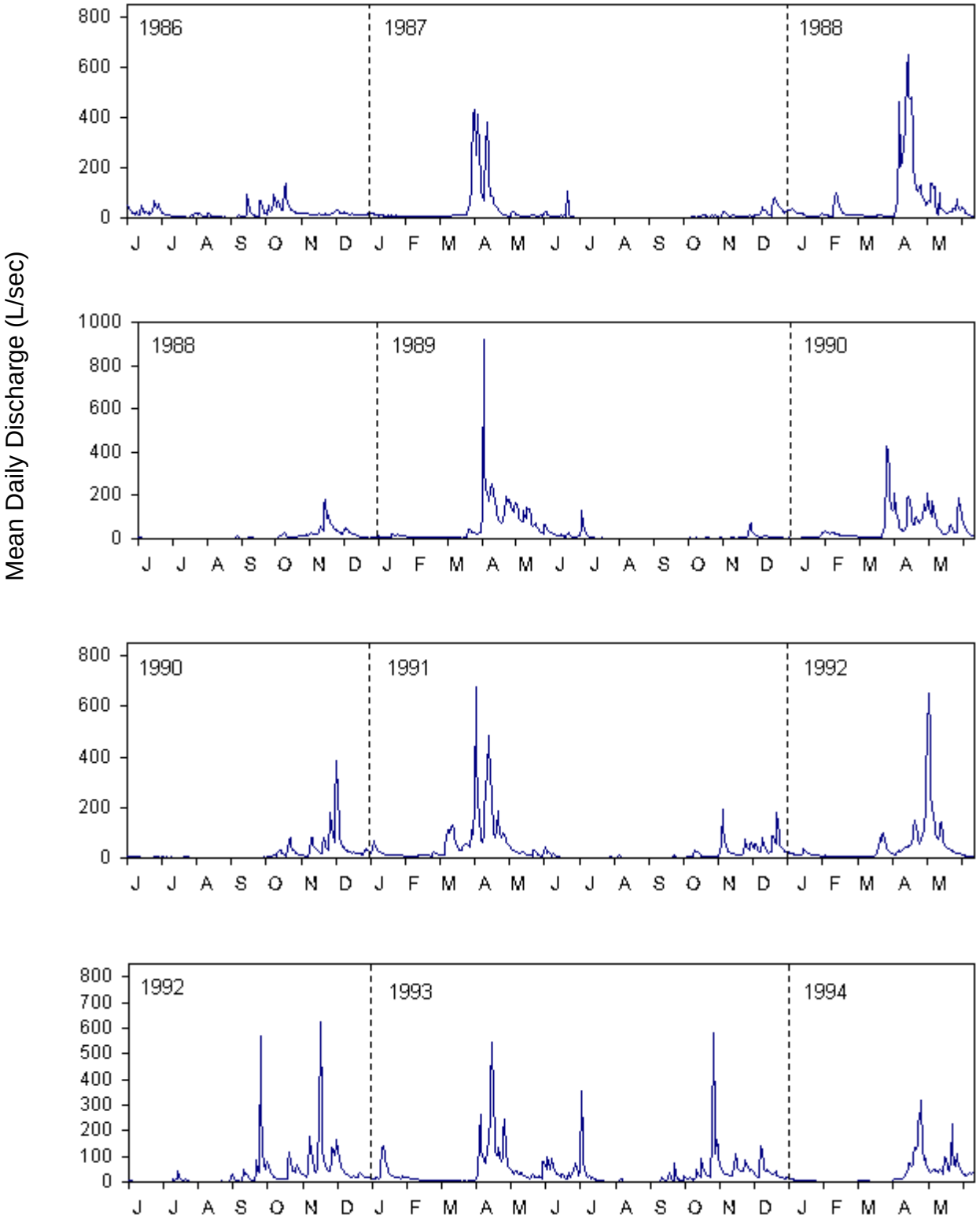
Harp Inflow 4 Hydrograph


Mean Daily Discharge (L/sec)
350
300
250
200
150
100
50
0
2002
2003
2004
J J A S O N D J F M A M J J A S O N D J F M A M
2004
2005
2006
J J A S O N D J F M A M J J A S O N D J F M A M
2006
2007
J J A S O N D J F M A M

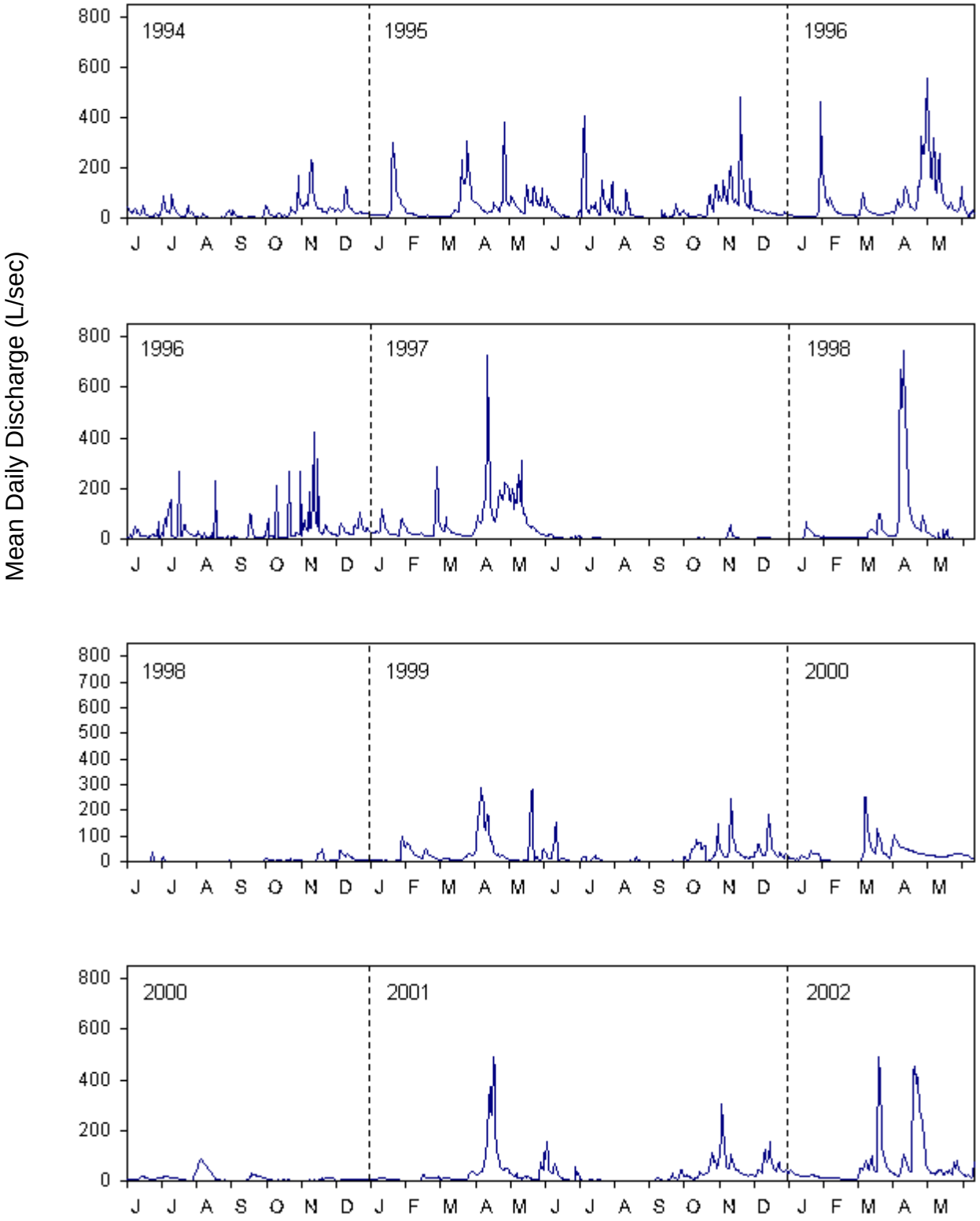
Harp Inflow 5 Hydrograph



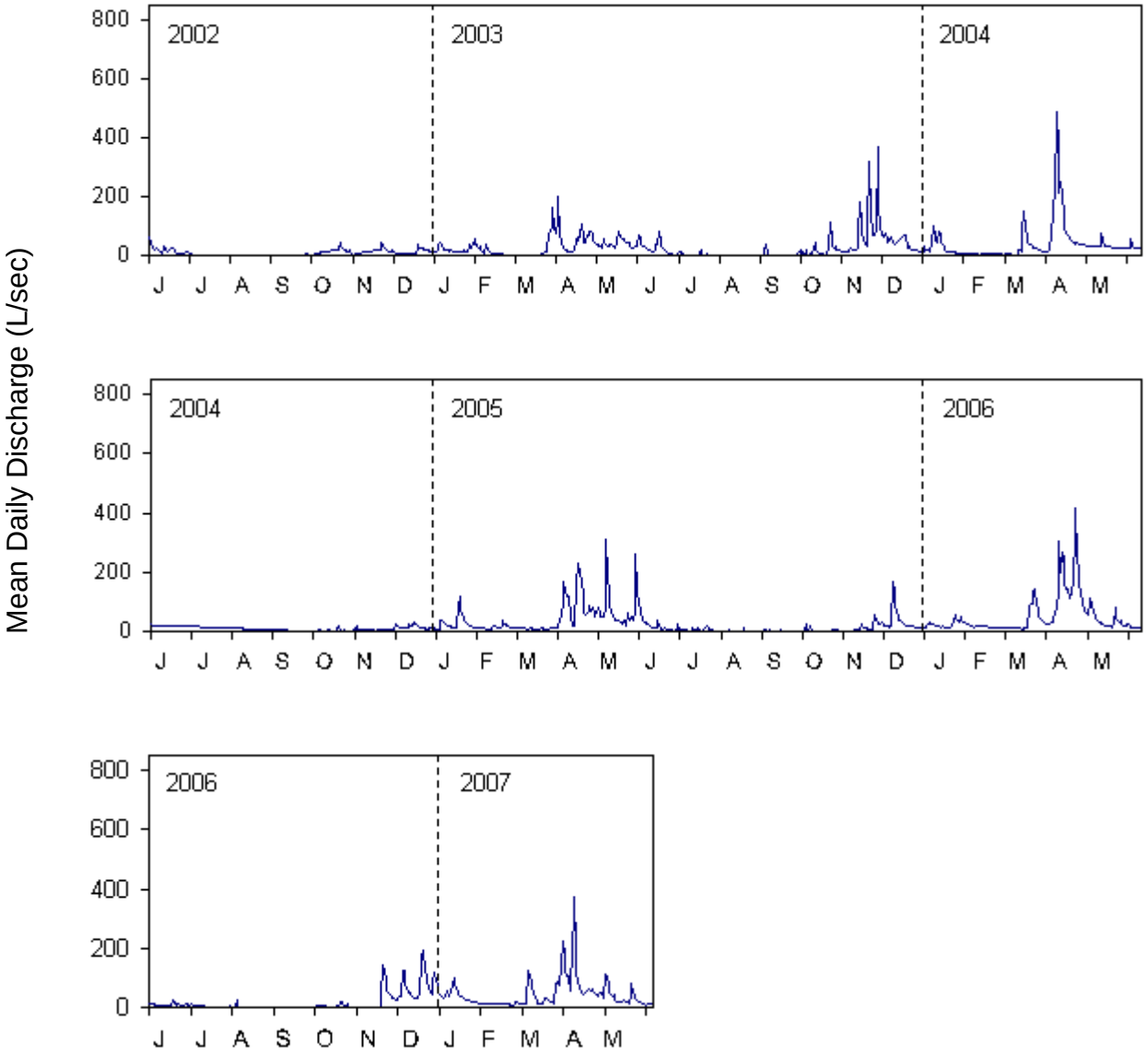
Harp Inflow 5 Hydrograph



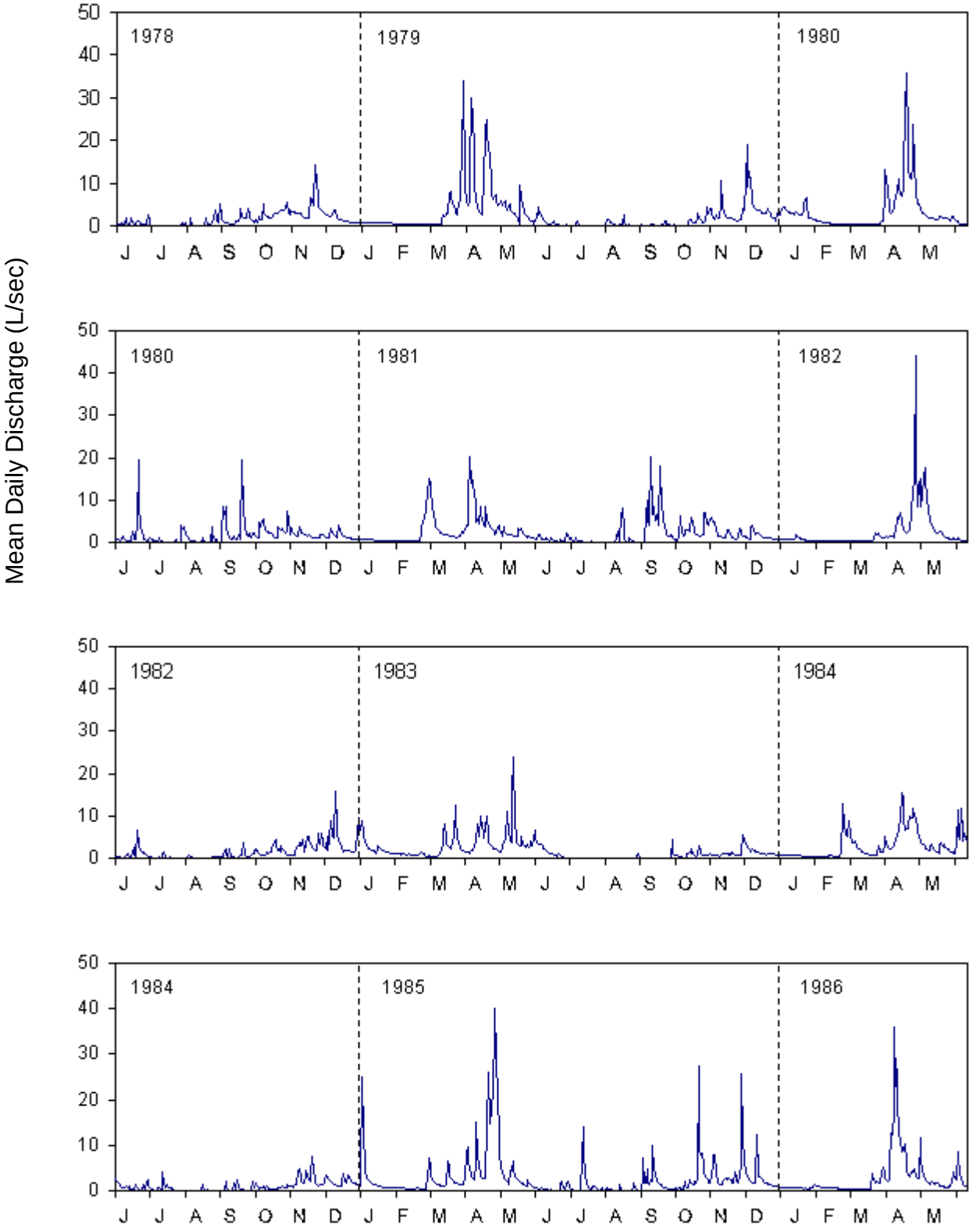
Harp Inflow 5 Hydrograph



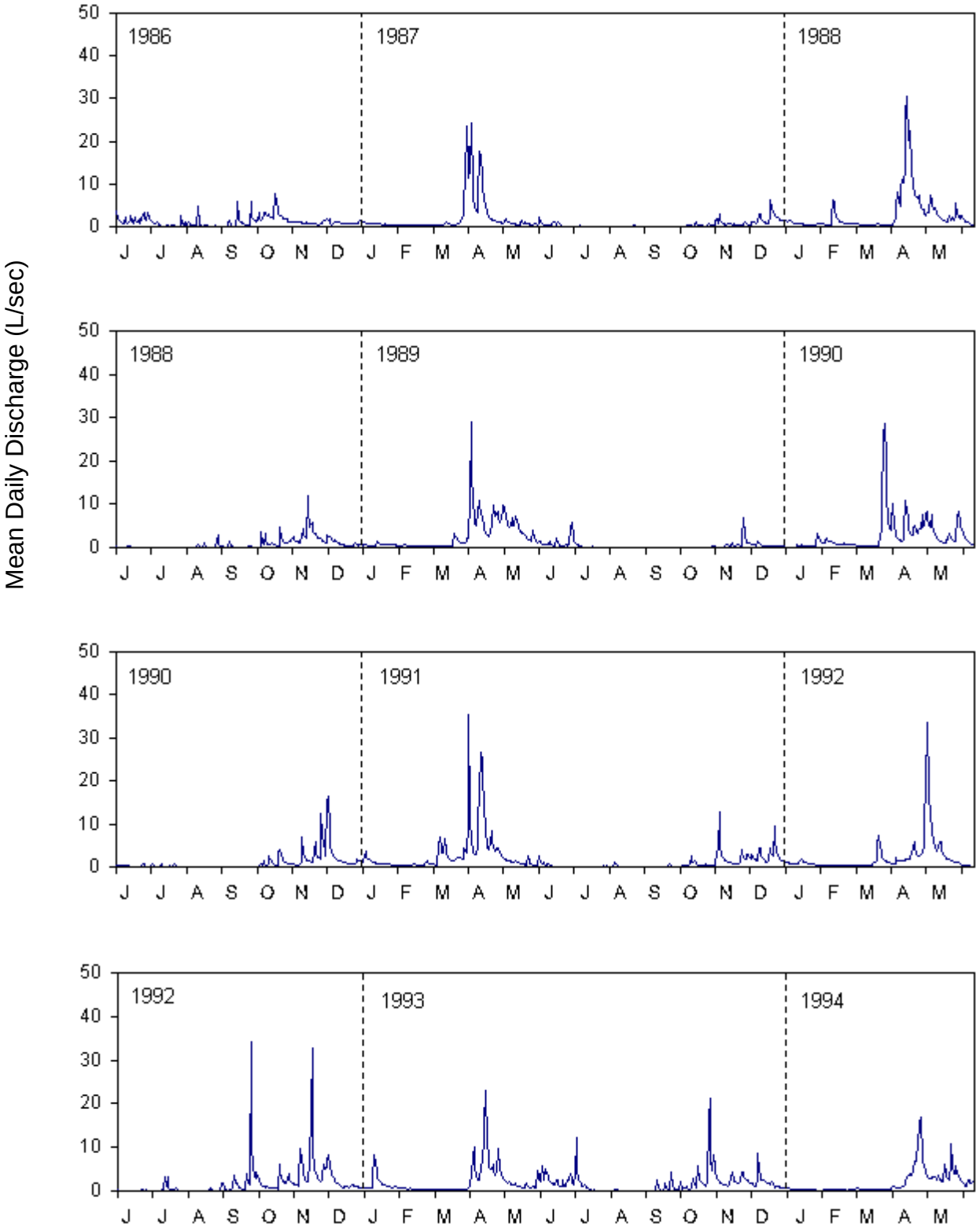
Harp Inflow 5 Hydrograph


Mean Daily Discharge (L/sec)
800
600
400
200
0
2002
2003
2004
J J A S O N D J F M A M J J A S O N D J F M A M
2004
2005
2006
J J A S O N D J F M A M J J A S O N D J F M A M
2006
2007
J J A S O N D J F M A M

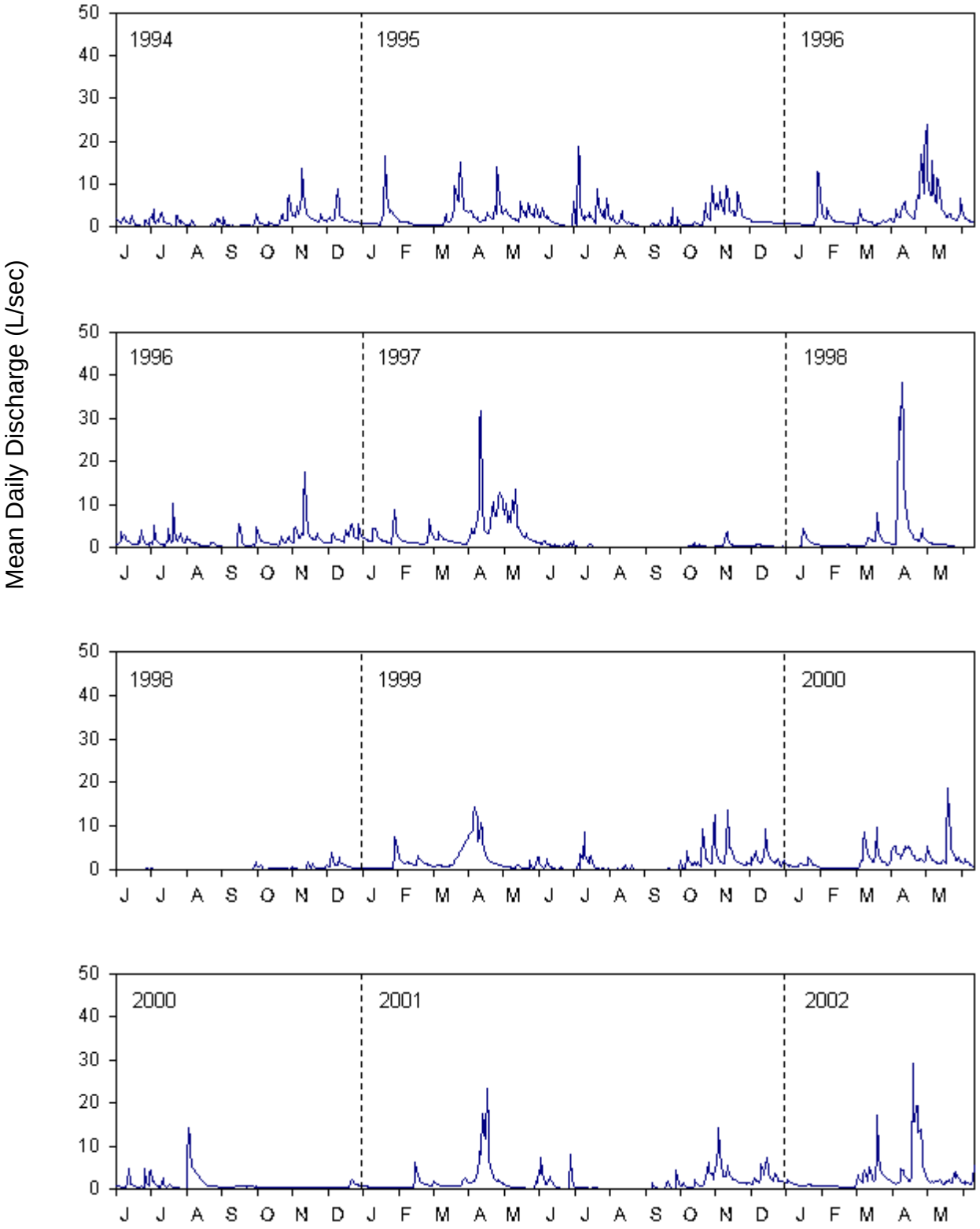
Harp Inflow 6 Hydrograph



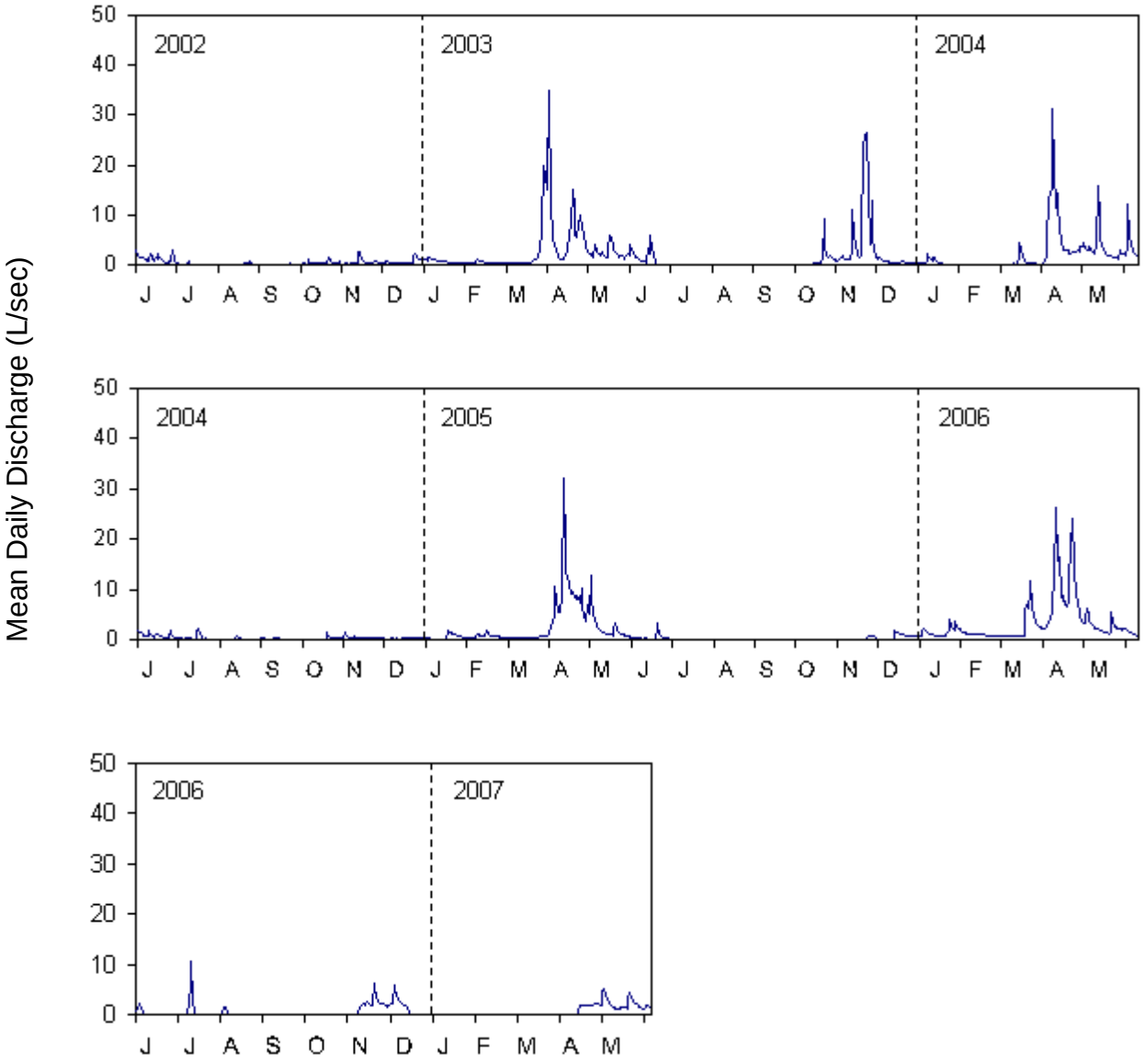
Harp Inflow 6 Hydrograph



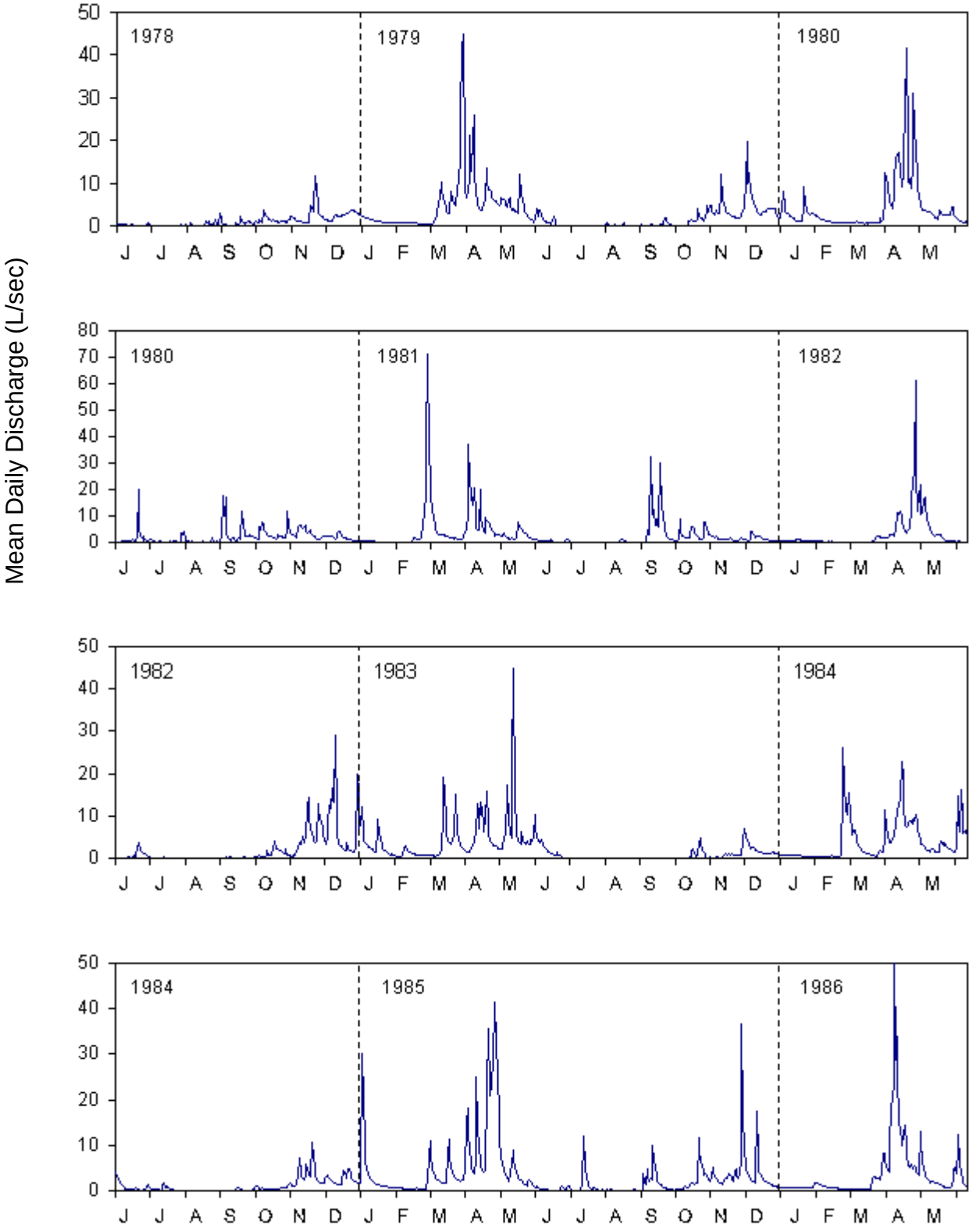
Harp Inflow 6 Hydrograph



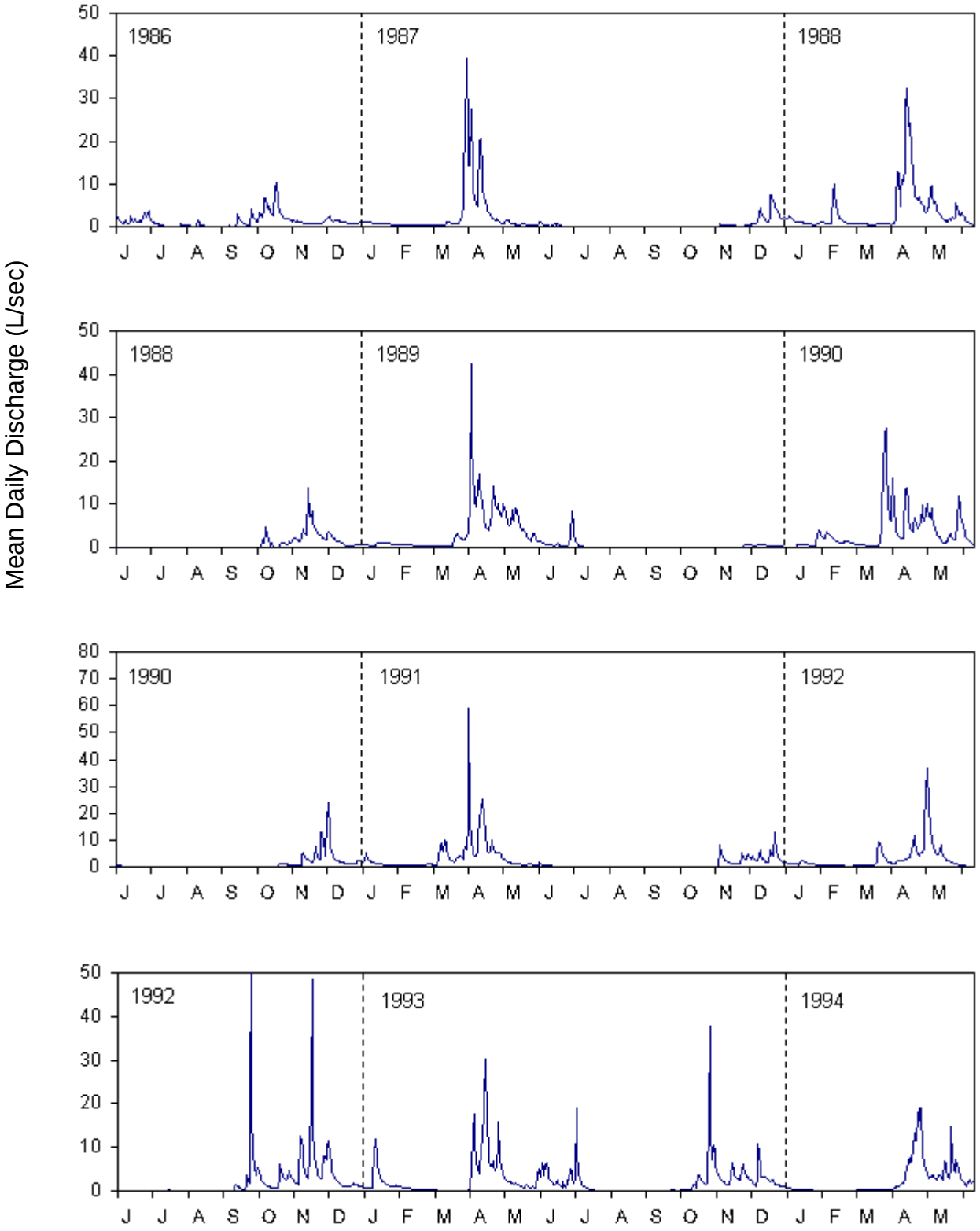
Harp Inflow 6 Hydrograph



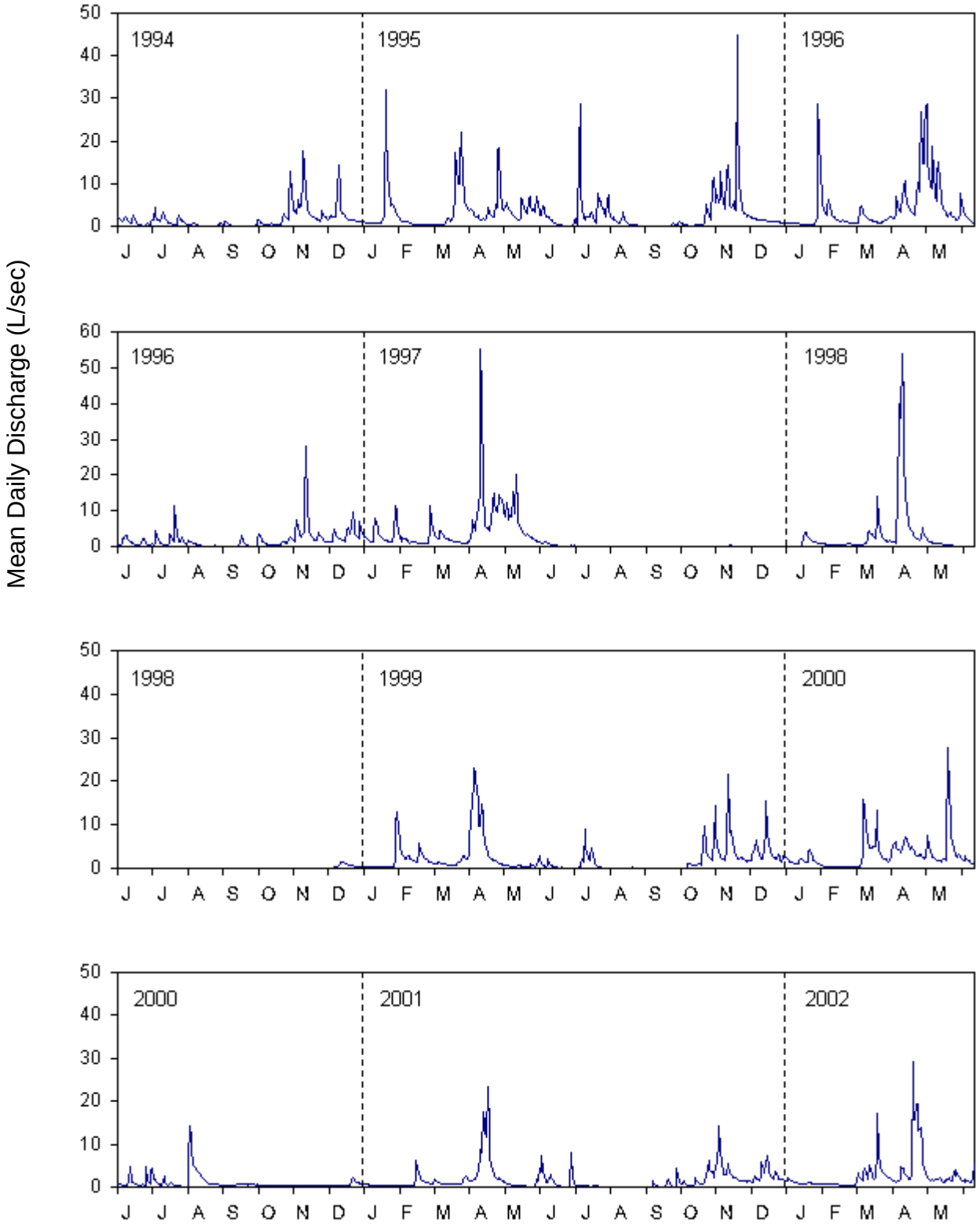
Harp Inflow 6a Hydrograph



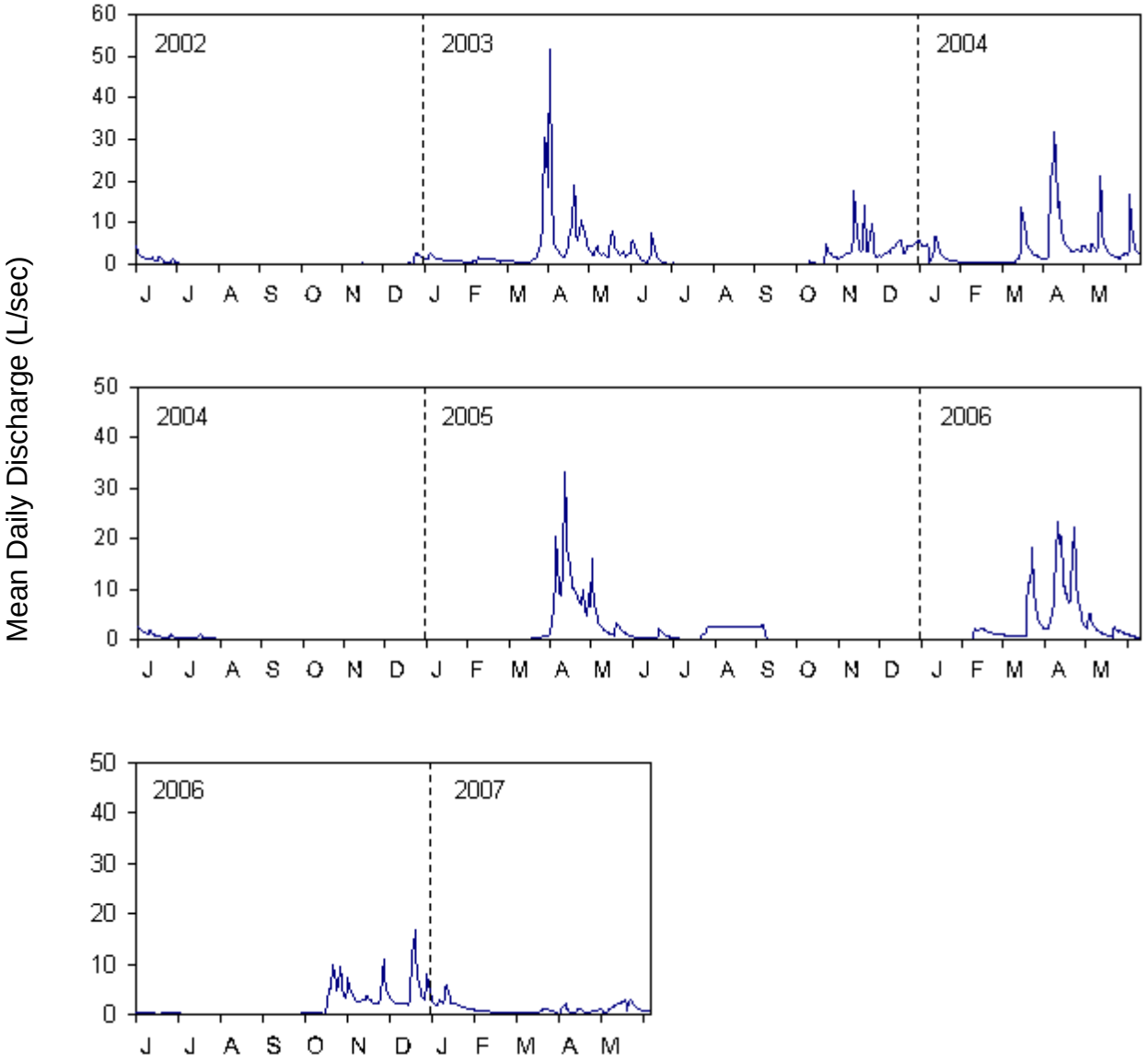
Harp Inflow 6a Hydrograph



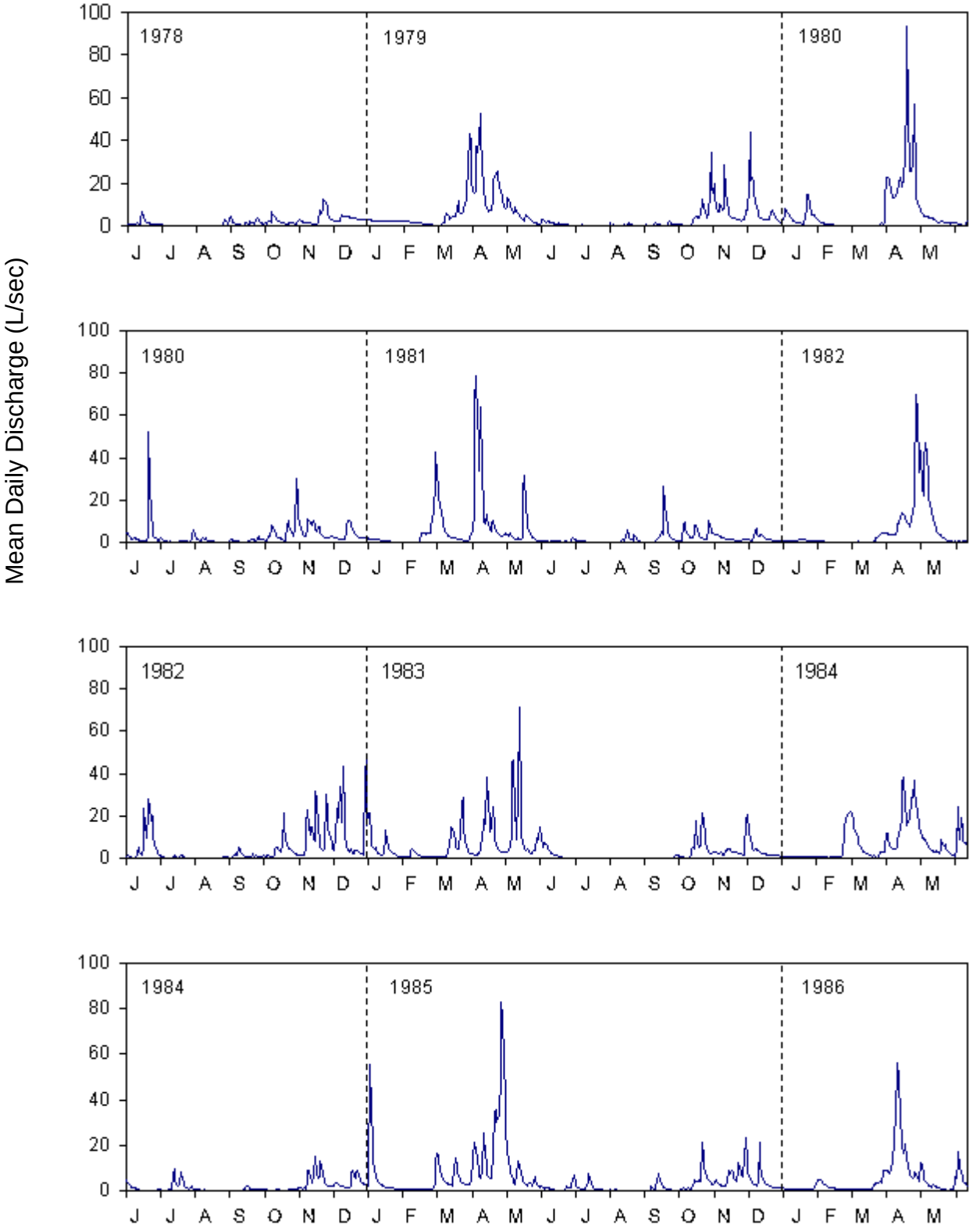
Harp Inflow 6a Hydrograph



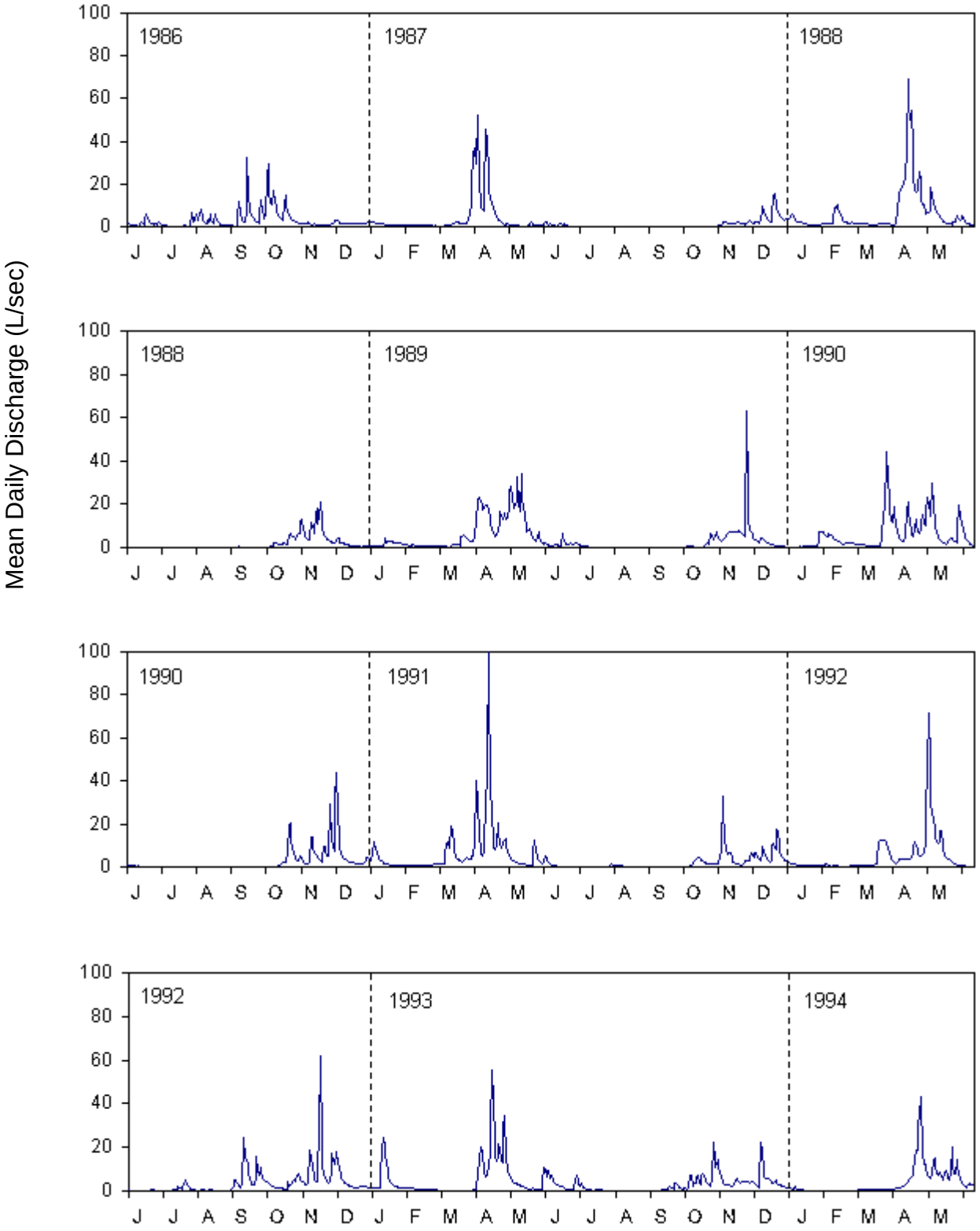
Harp Inflow 6a Hydrograph



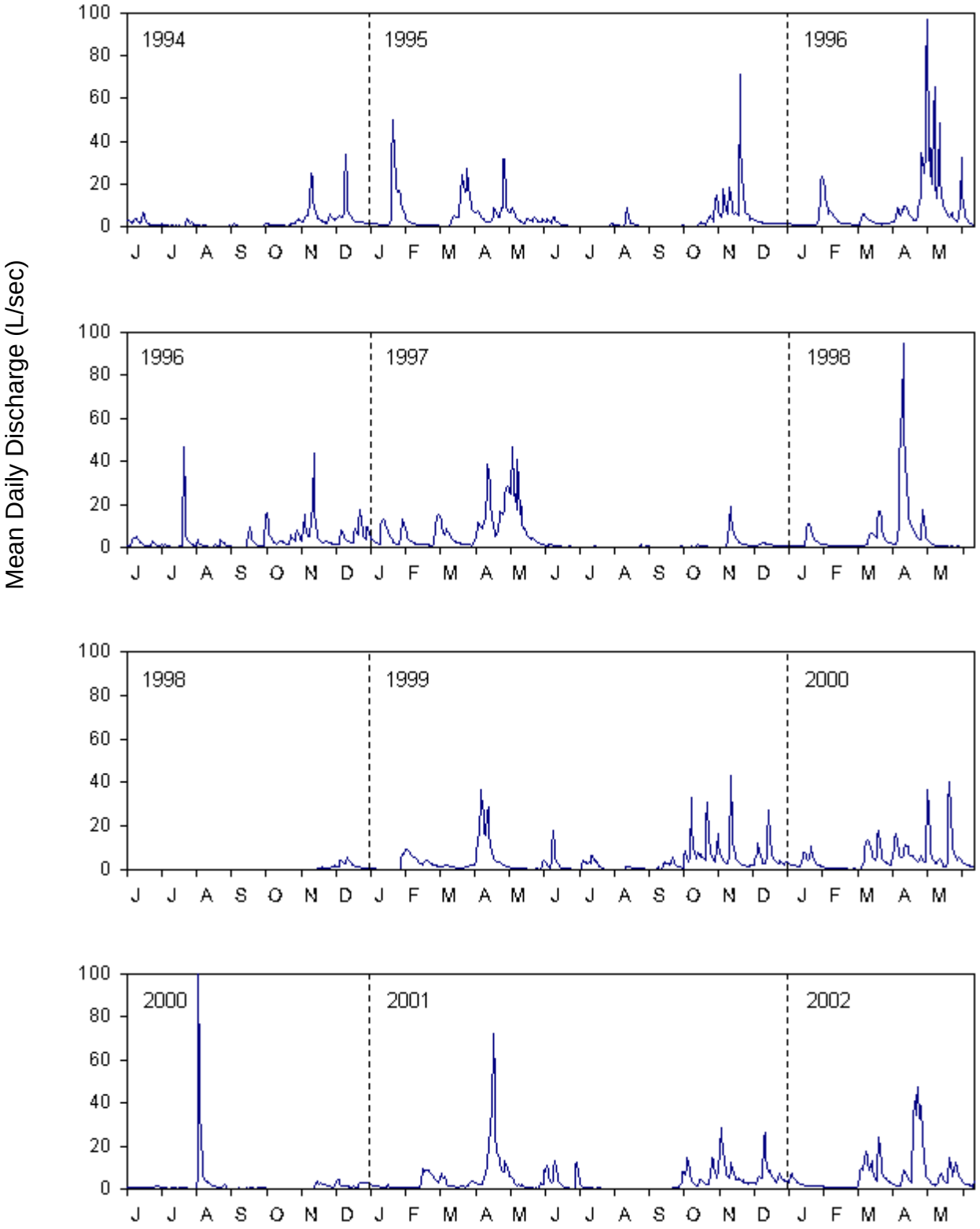
Plastic Inflow 1 Hydrograph



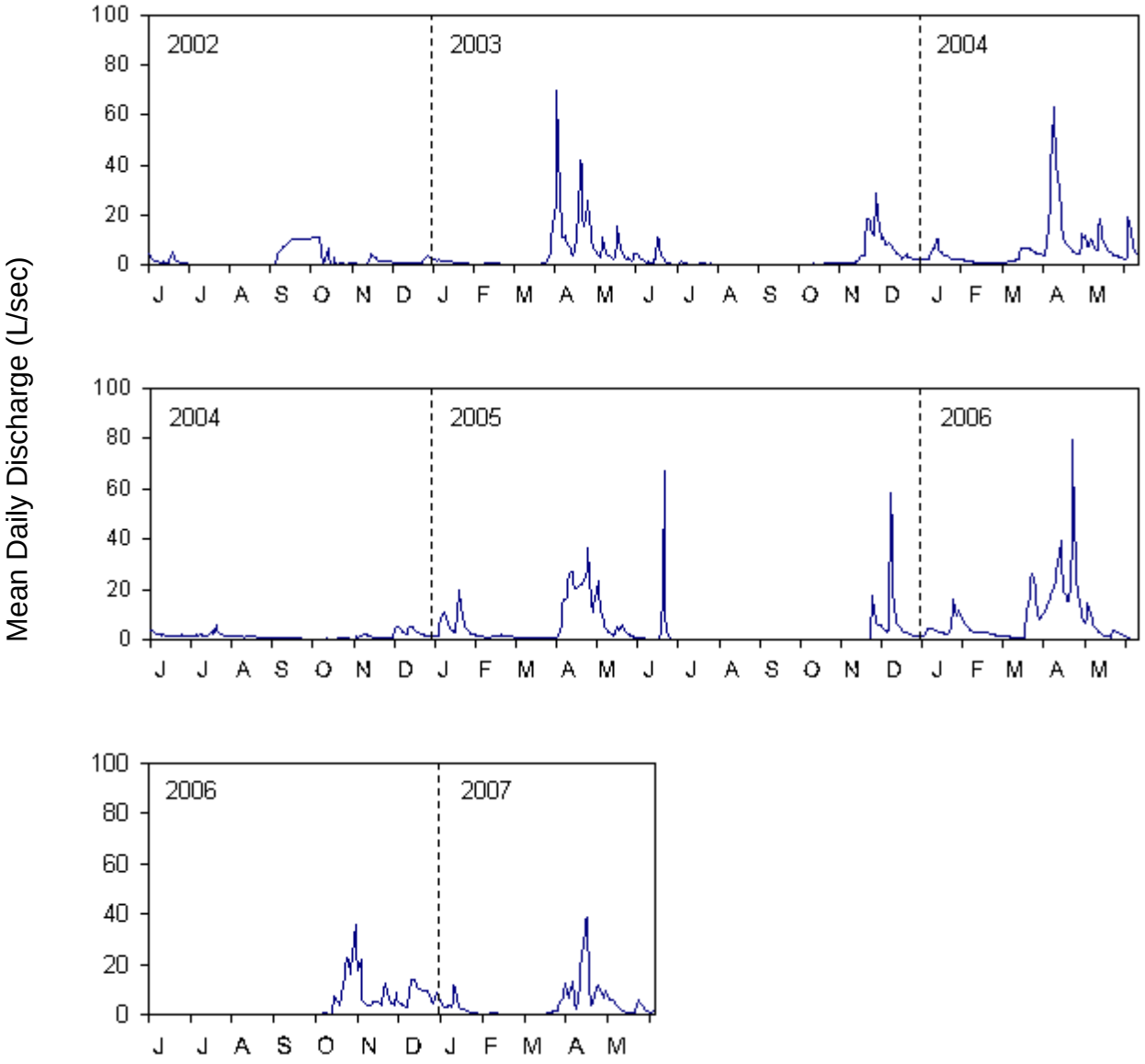
Plastic Inflow 1 Hydrograph



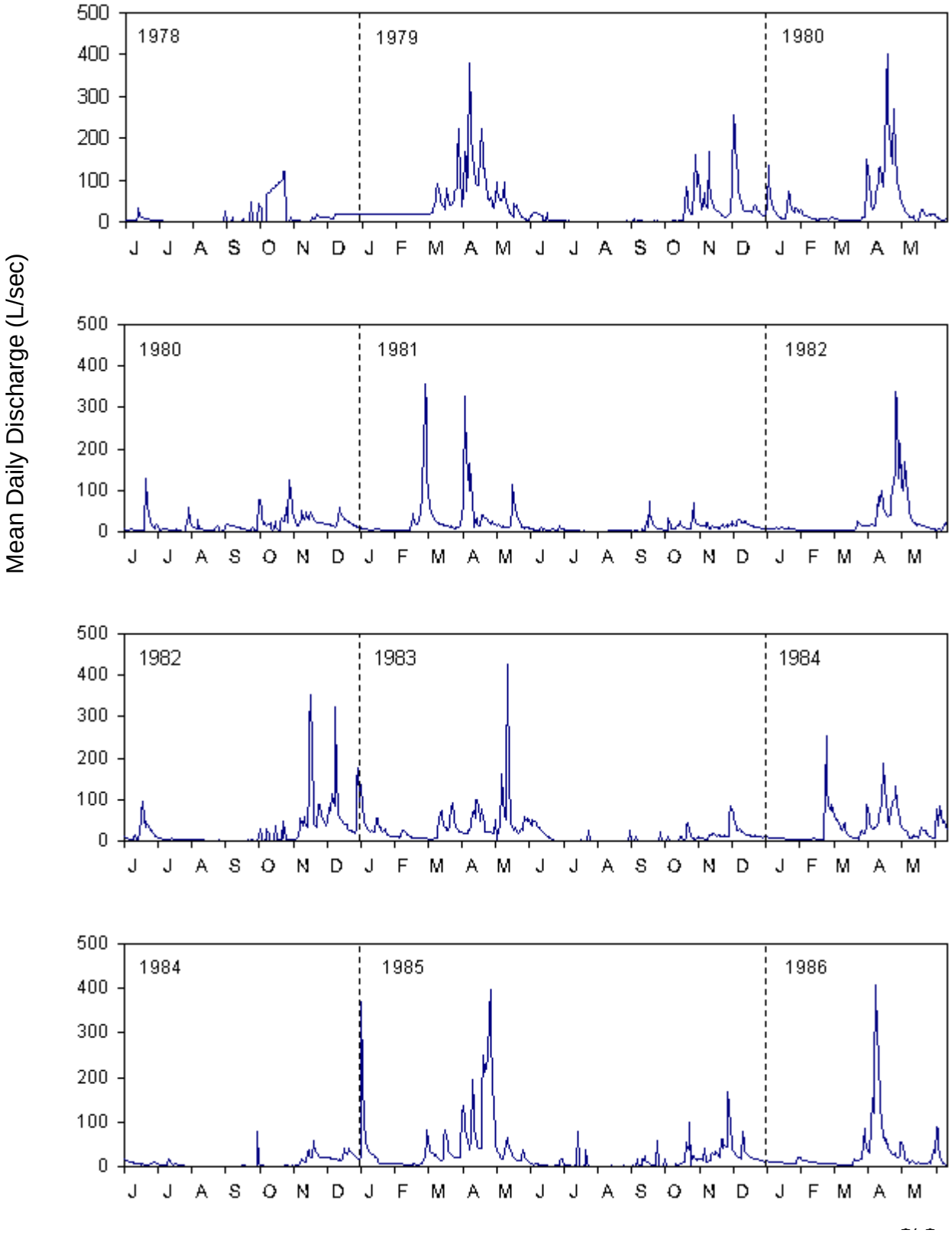
Plastic Inflow 1 Hydrograph



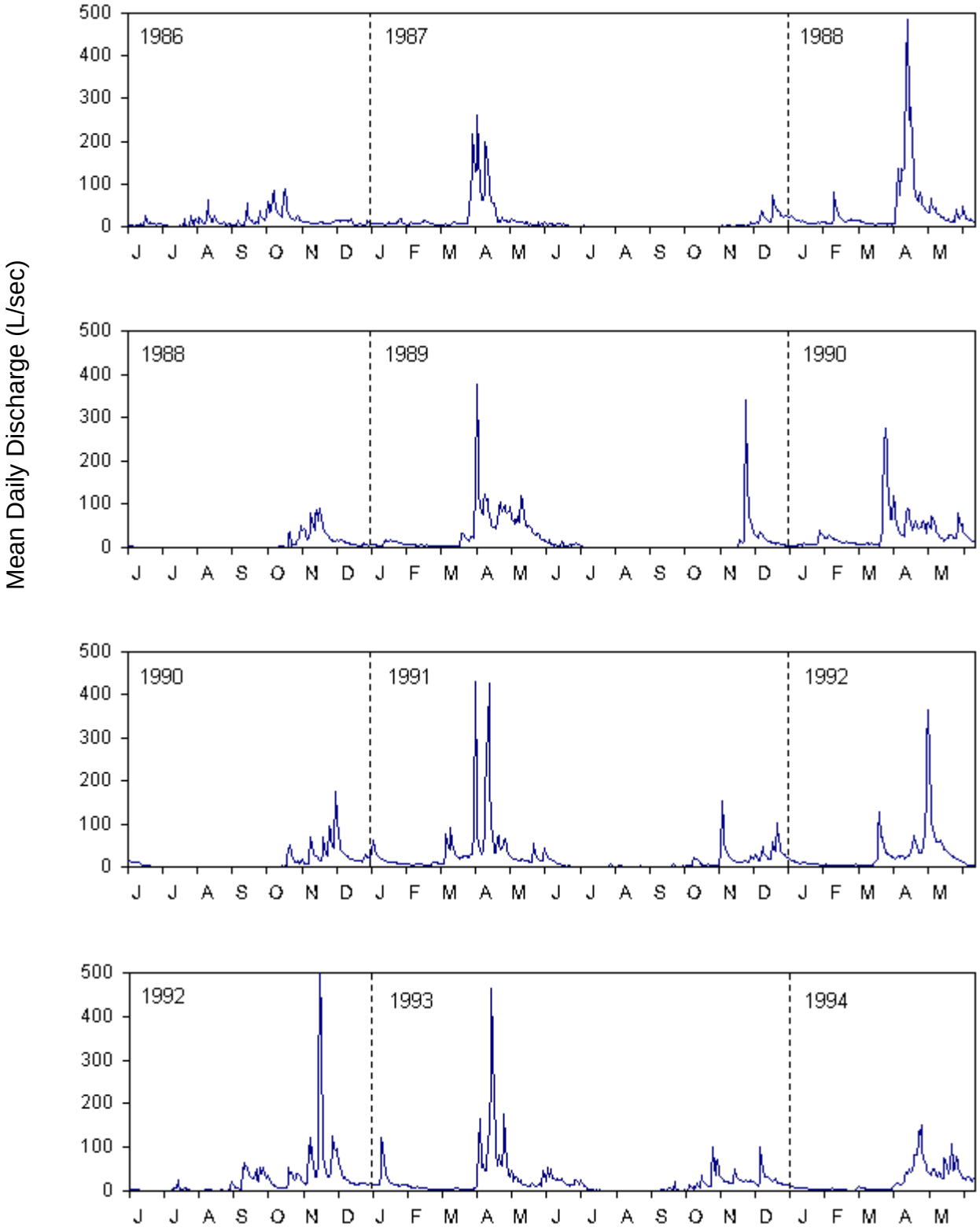
Plastic Inflow 1 Hydrograph


Mean Daily Discharge (L/sec)
100
80
60
40
20
0
2002
2003
2004
J J A S O N D J F M A M J J A S O N D J F M A M
2004
2005
2006
J J A S O N D J F M A M J J A S O N D J F M A M
2006
2007
J J A S O N D J F M A M

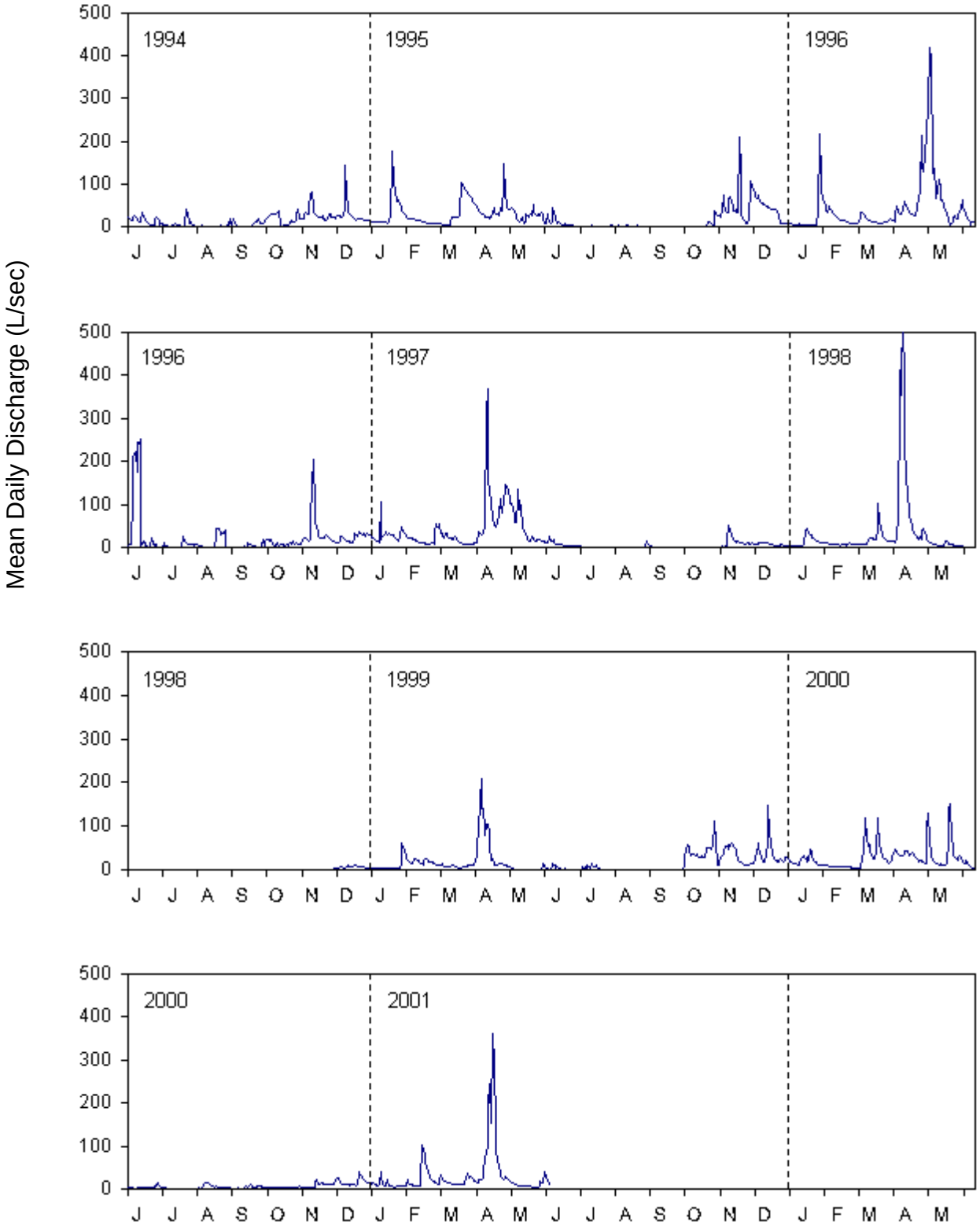
Red Chalk Inflow 1 Hydrograph



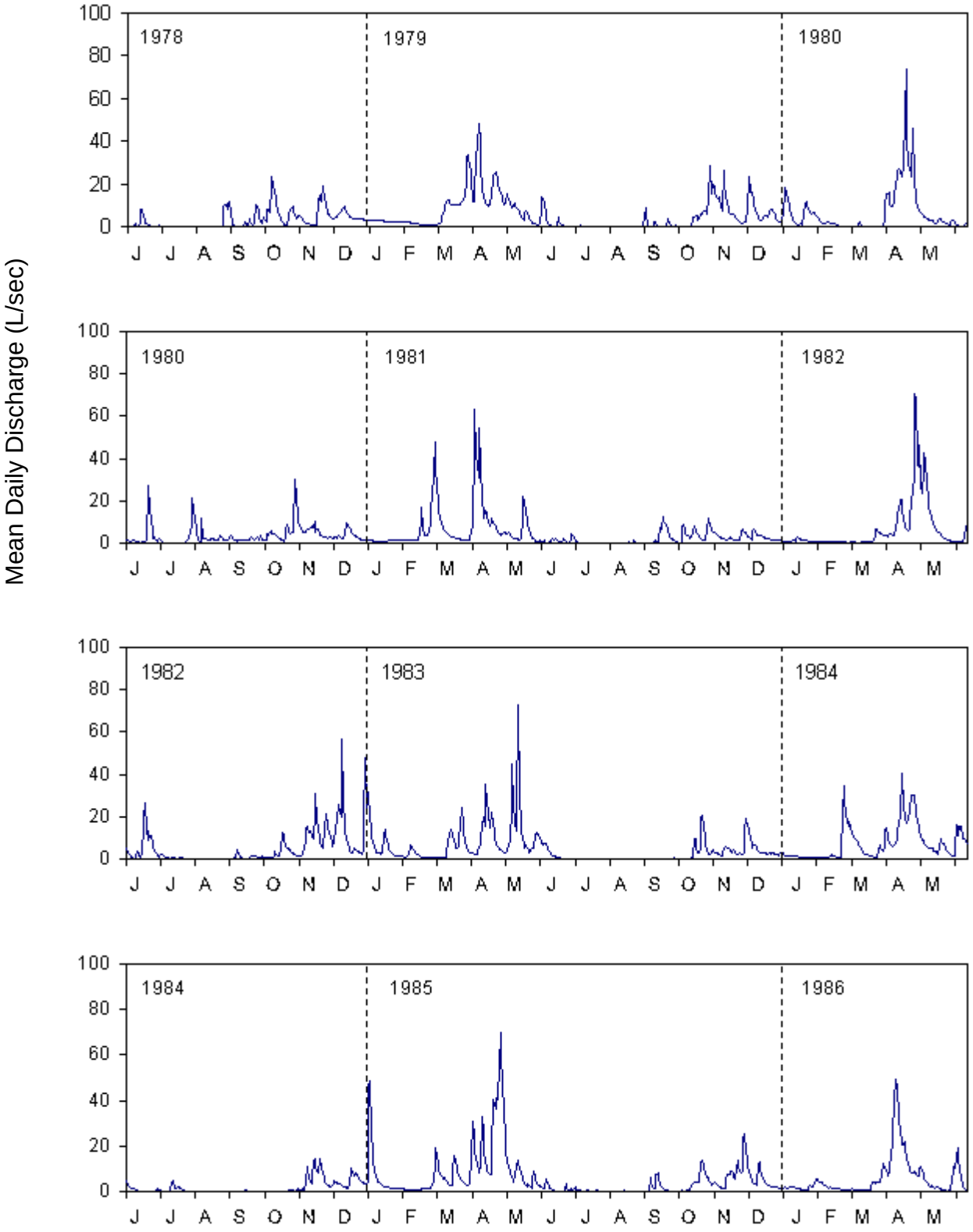
Redf Chalk Inflow 1 Hydrograph



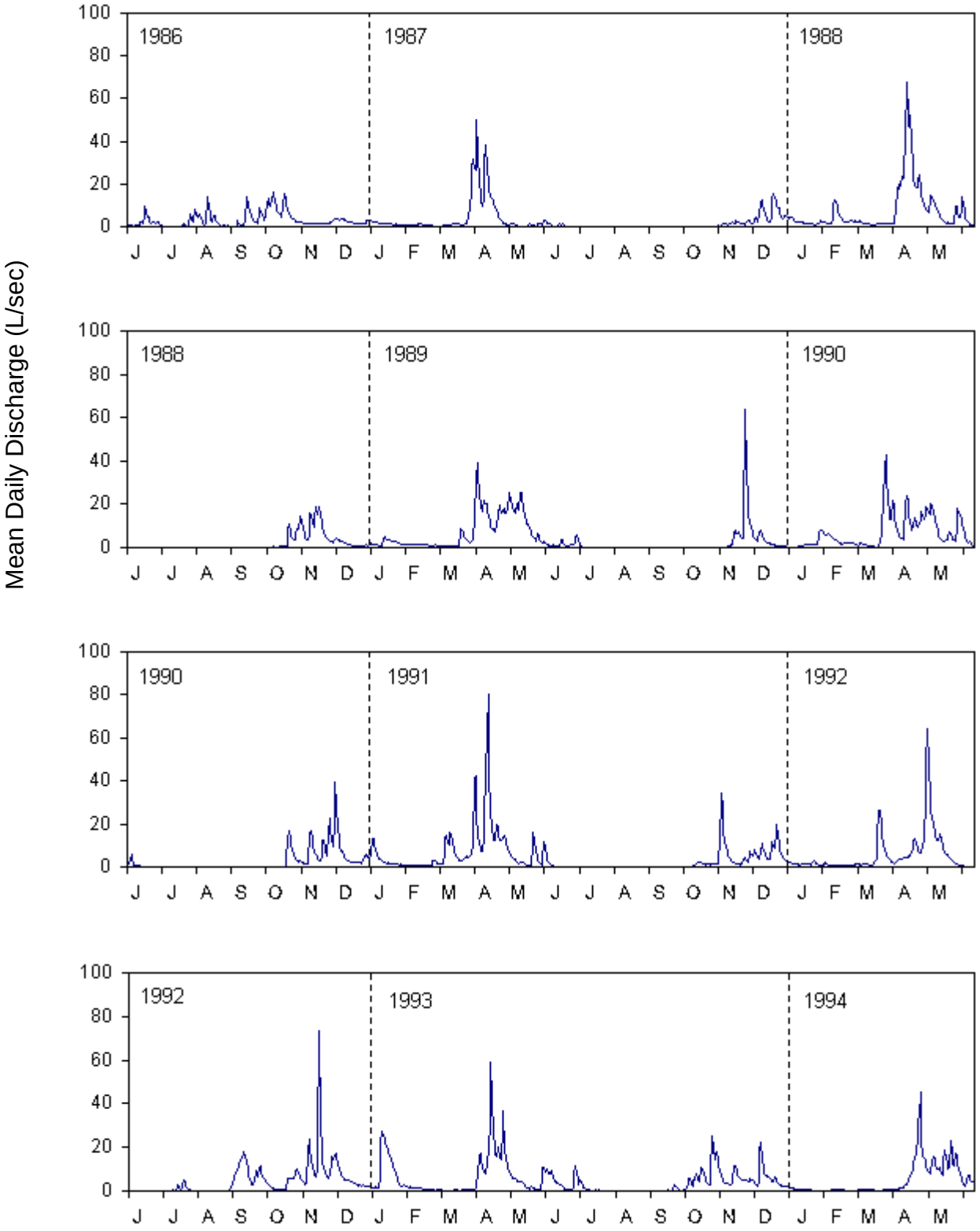
Red Chalk Inflow 1 Hydrograph



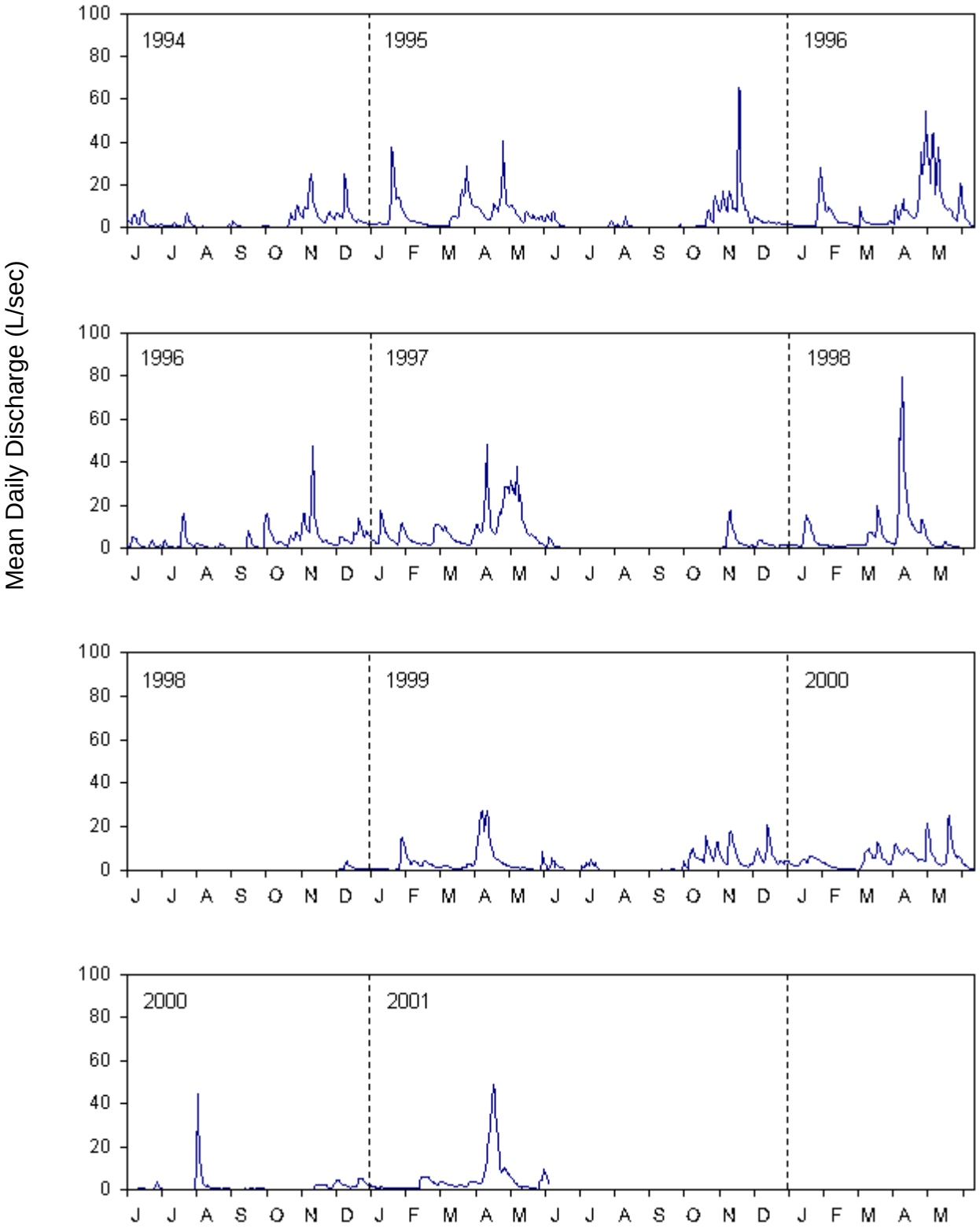
Red Chalk Inflow 2 Hydrograph



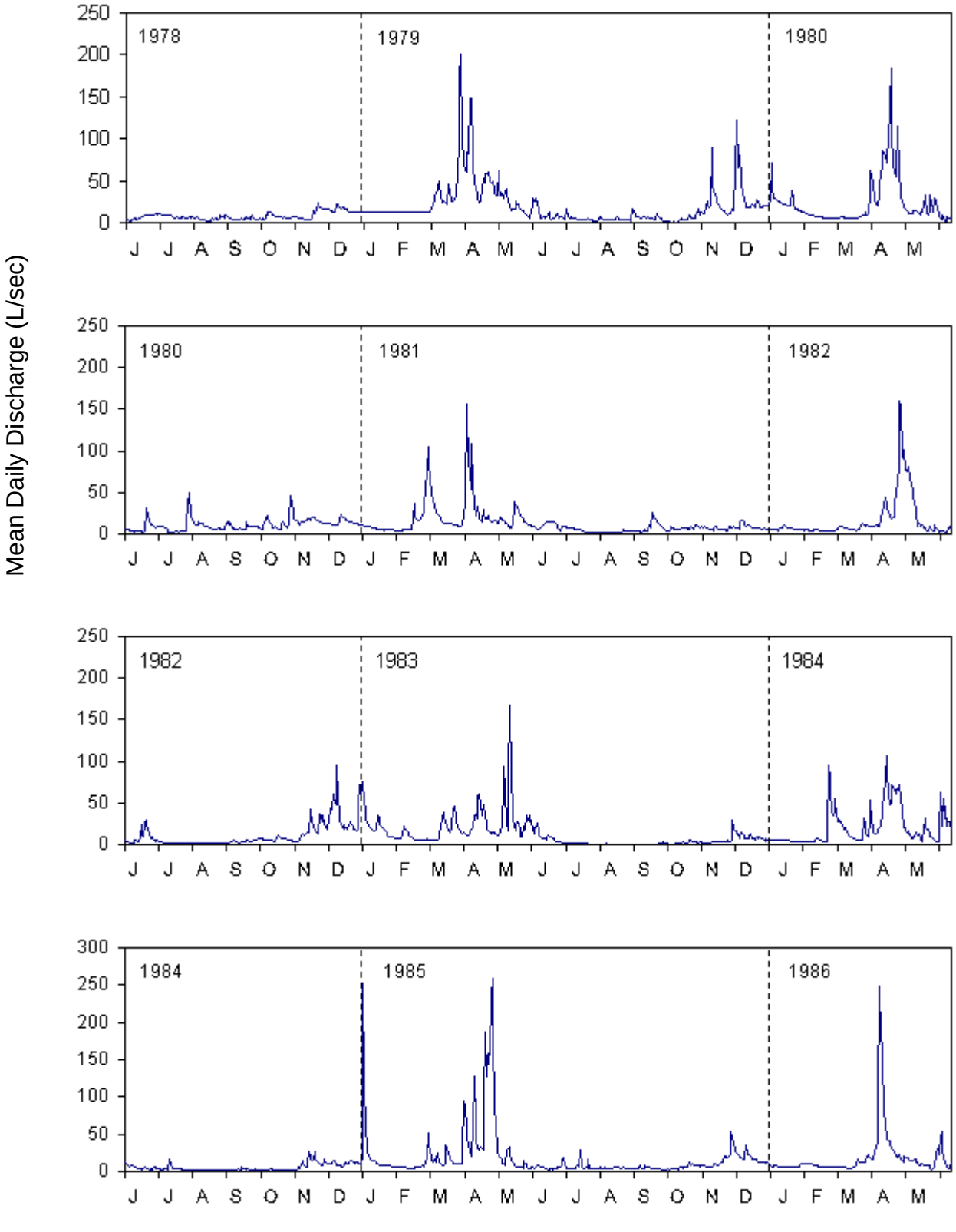
Red Chalk Inflow 2 Hydrograph



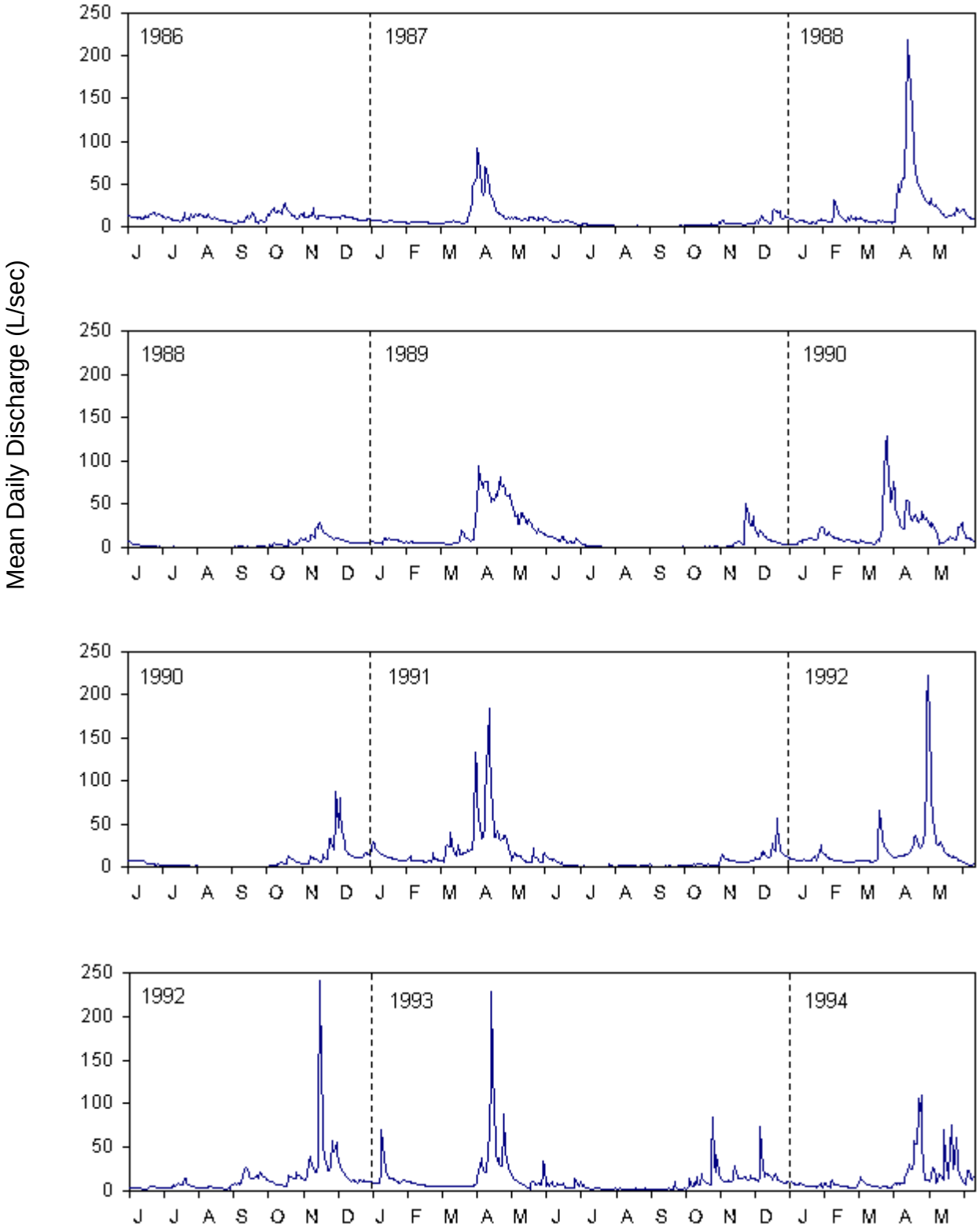
Red Chalk Inflow 2 Hydrograph



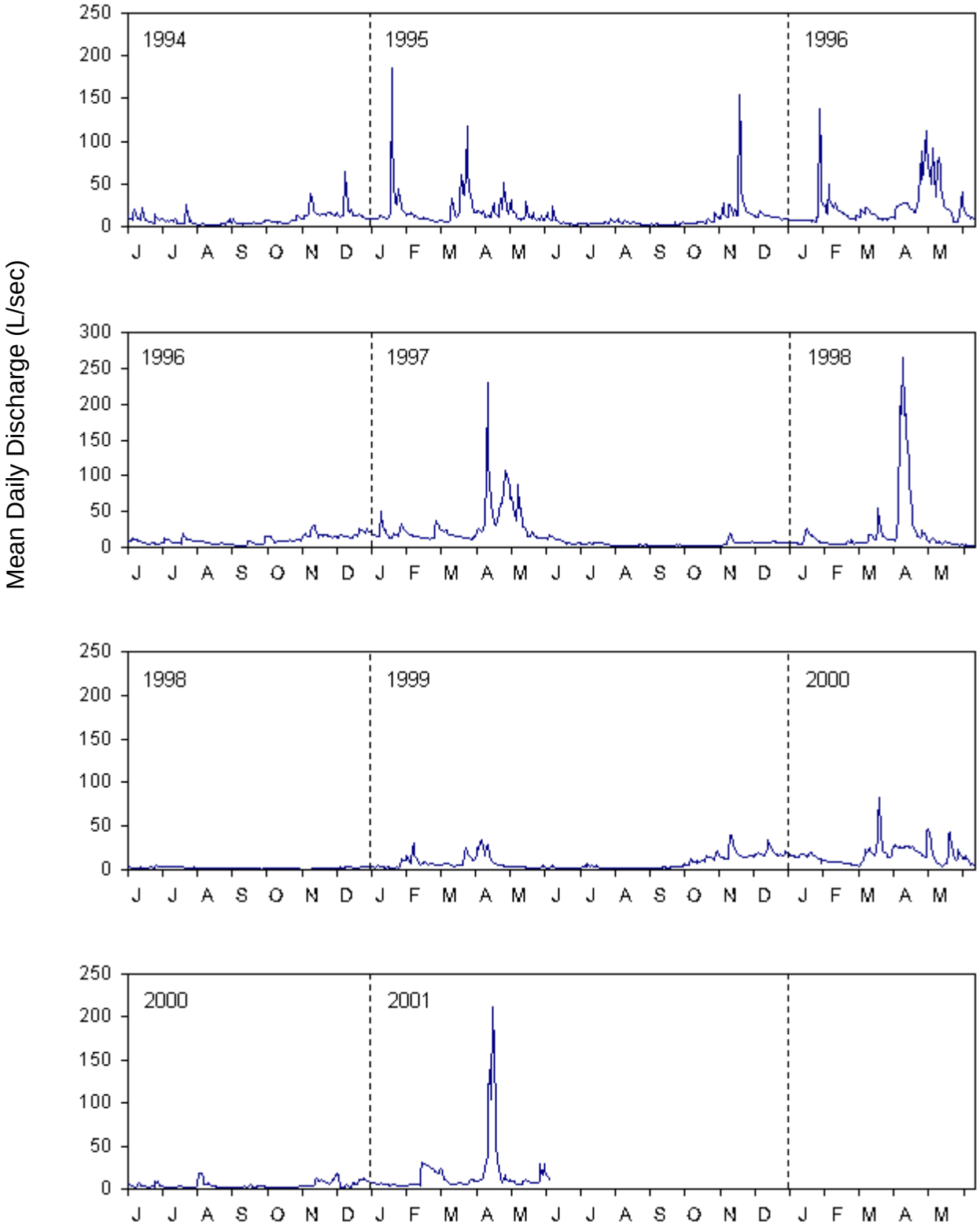
Red Chalk Inflow 3 Hydrograph



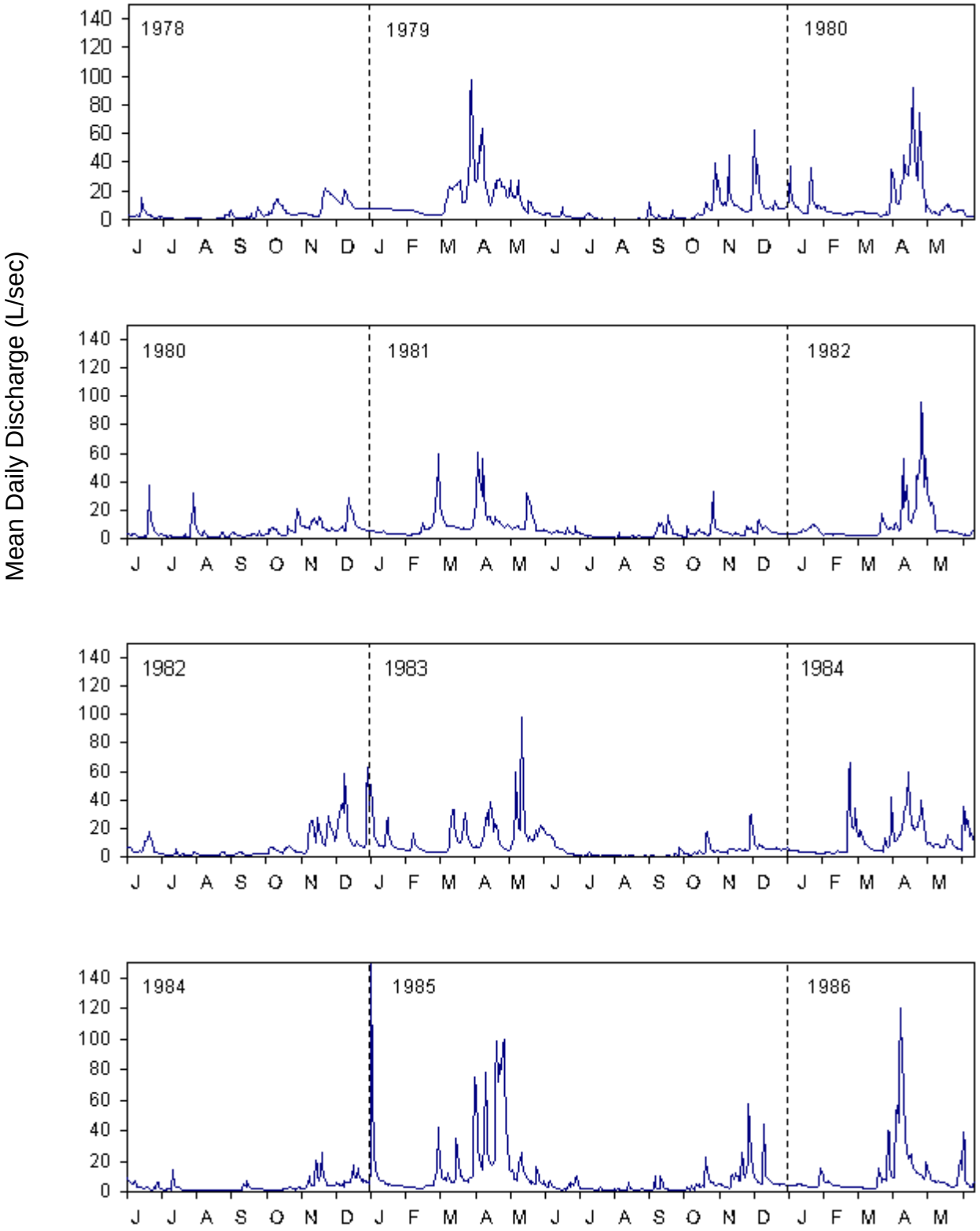
Red Chalk Inflow 3 Hydrograph



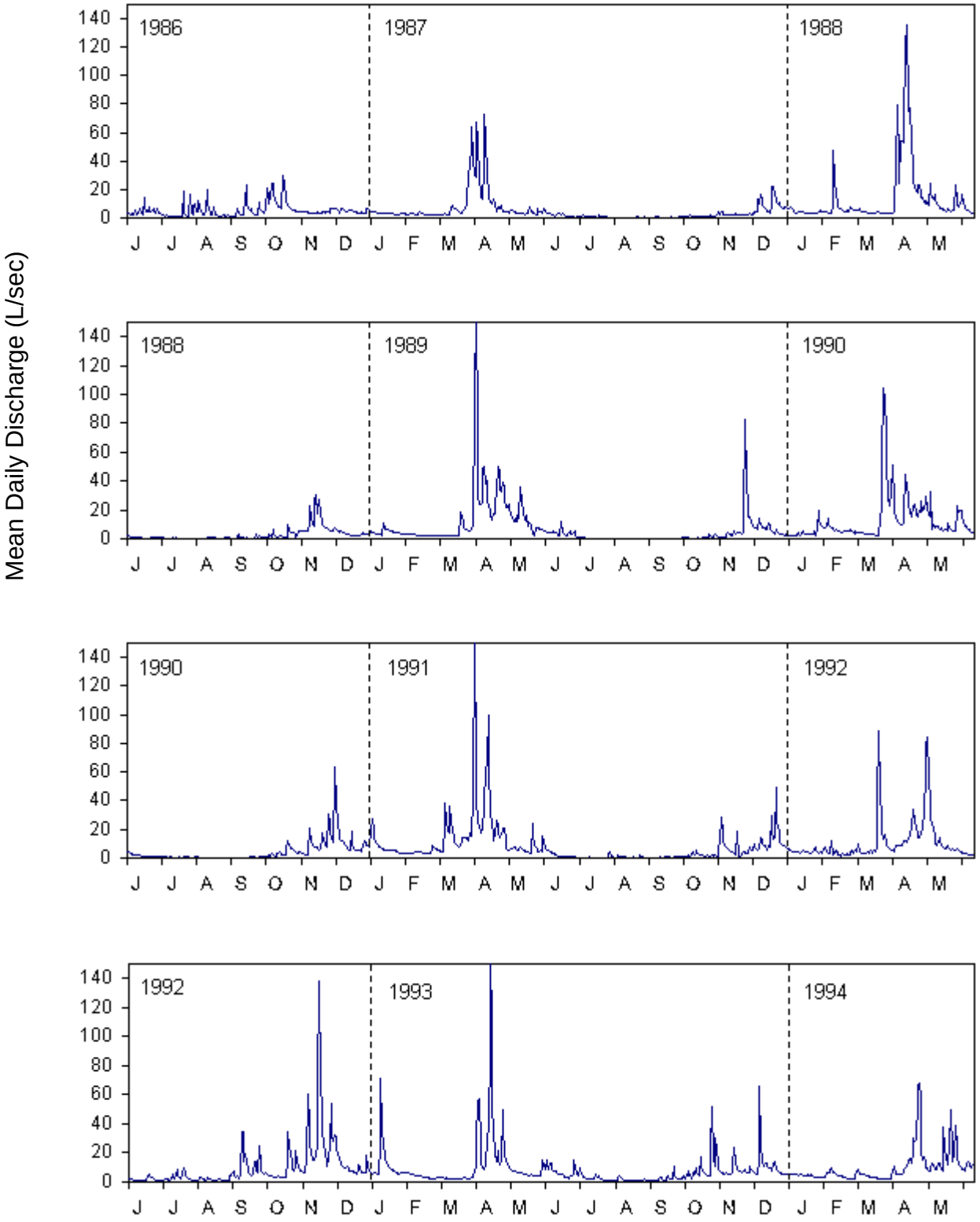
Red Chalk Inflow 3 Hydrograph



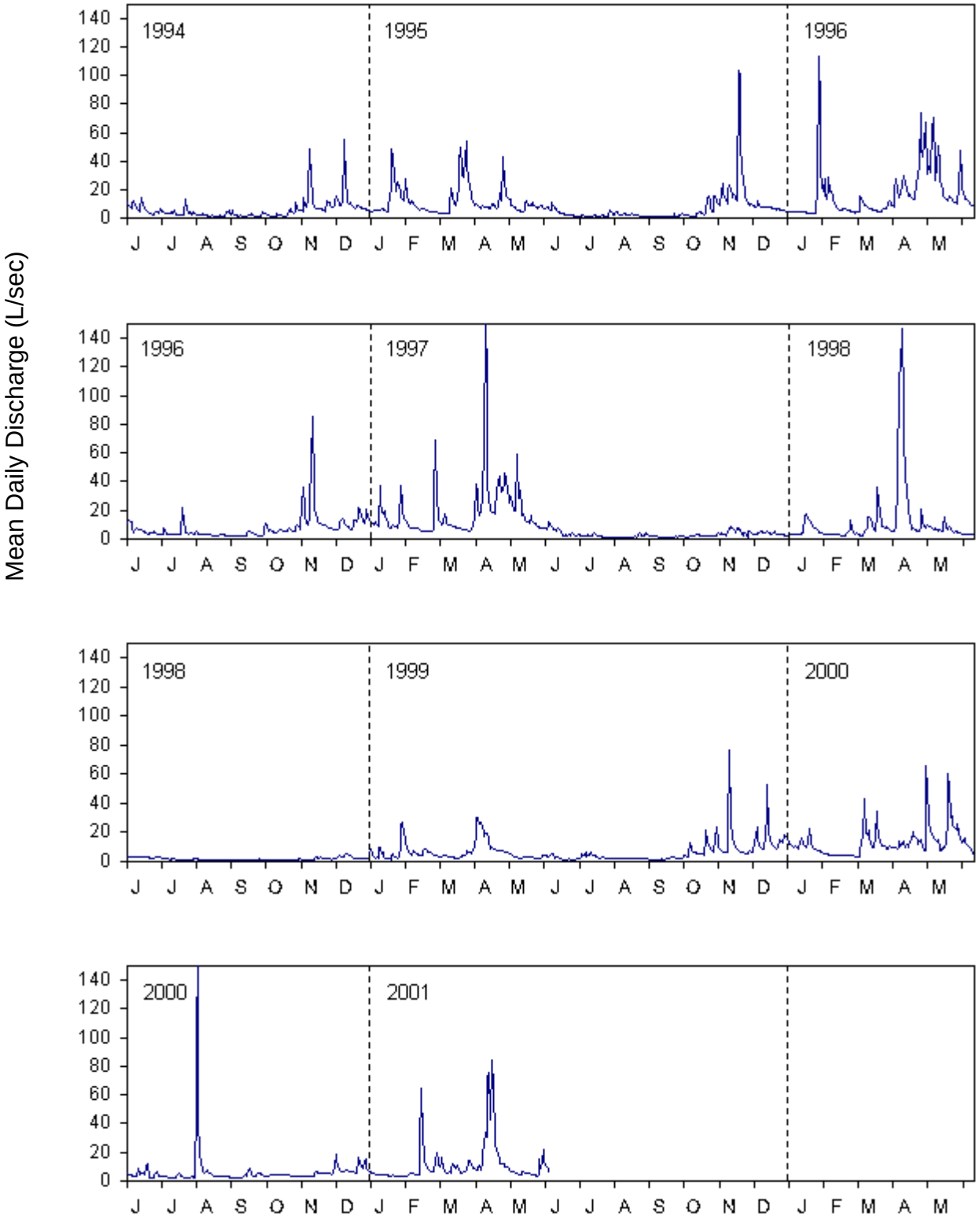
Red Chalk Inflow 4 Hydrograph



Red Chalk Inflow 4 Hydrograph



Red Chalk Inflow 4 Hydrograph

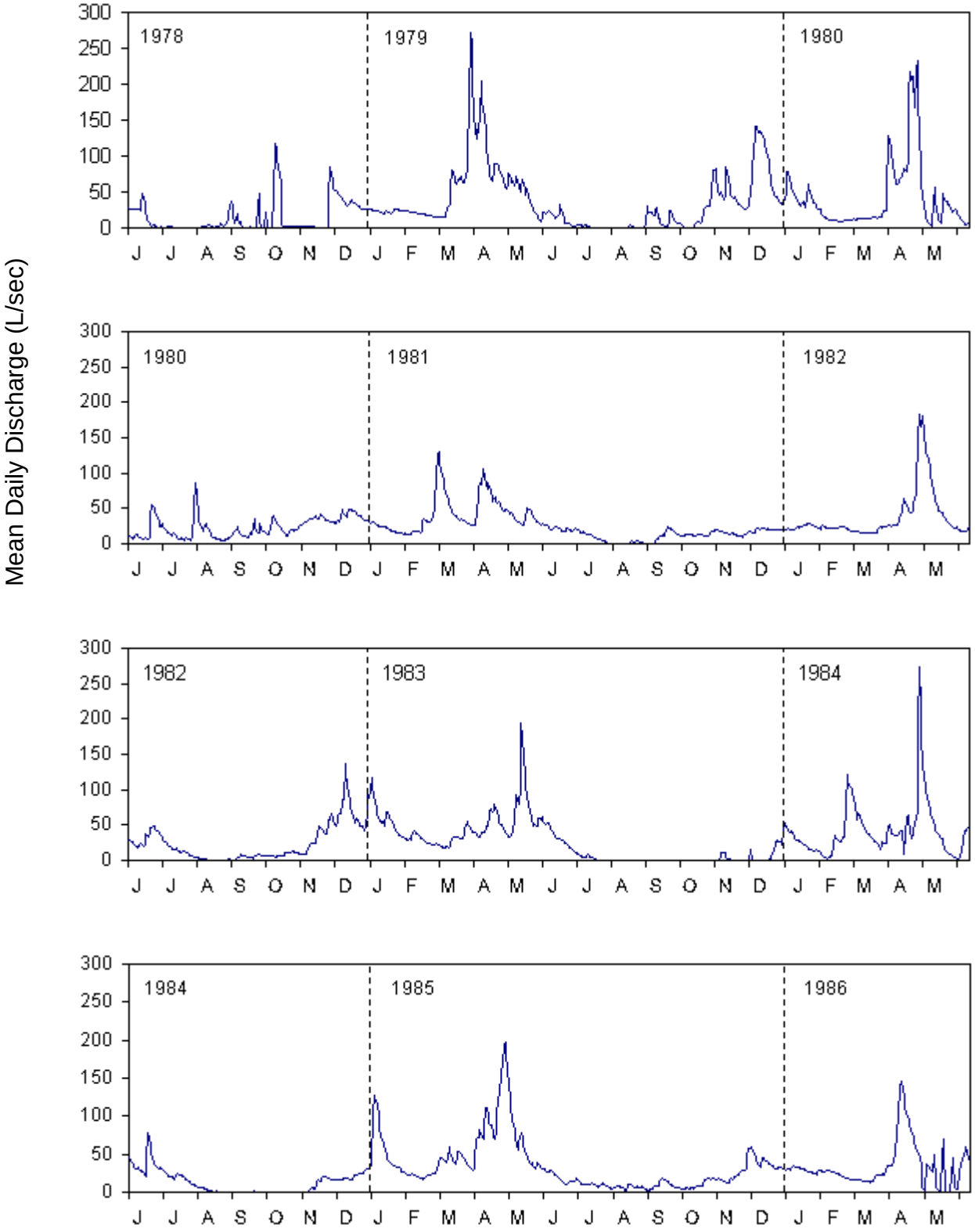


Appendix B

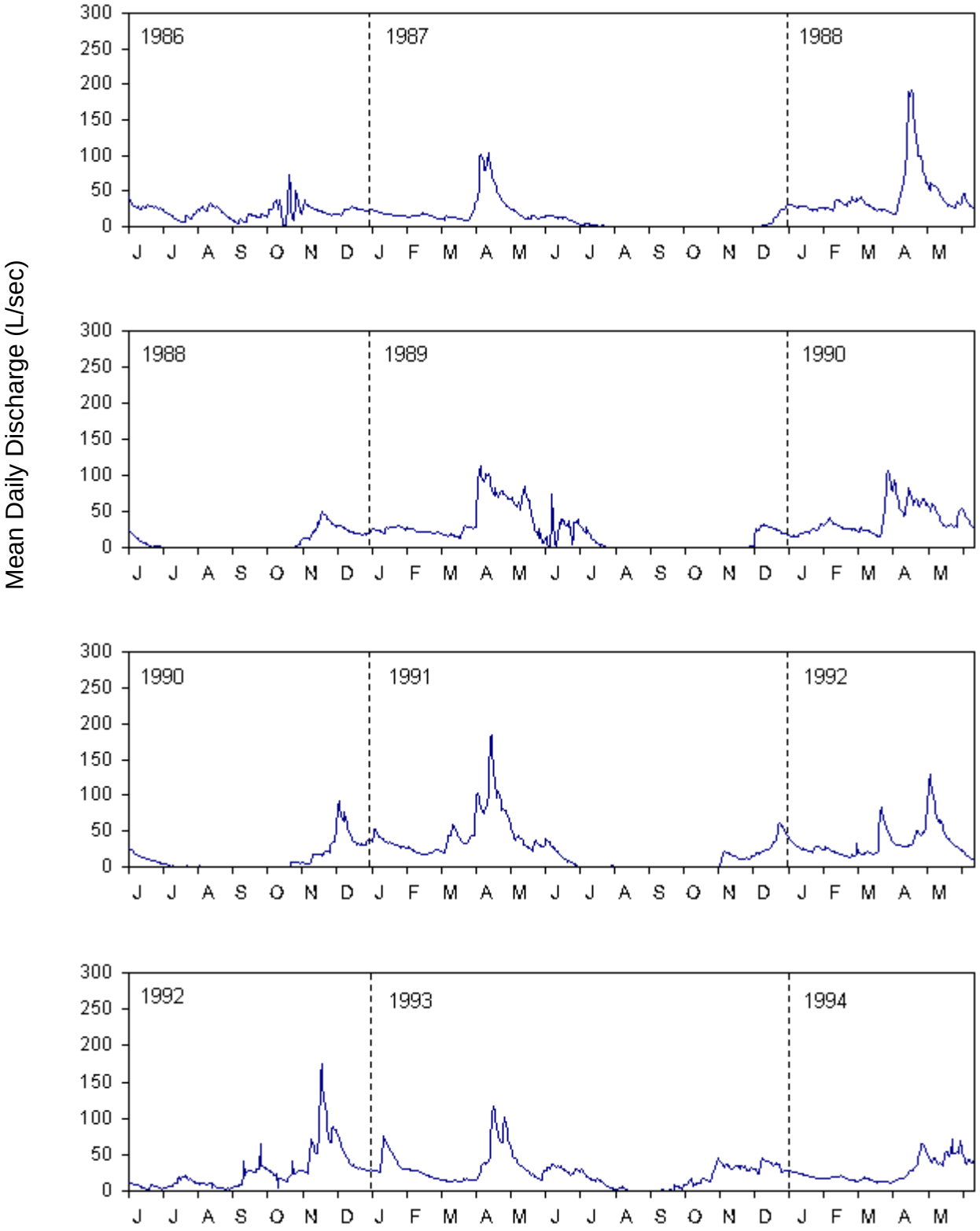
Mean daily discharges (L/sec) for 8 outlet streams of the 8 lakes, 1978-2007

Blue Chalk	1978-2001
Chub	1978-2001
Crosson	1980-1993
Dickie	1978-2007
Harp	1978-2007
Heney	1980-1993
Plastic	1978-2007
Red Chalk	1978-2001

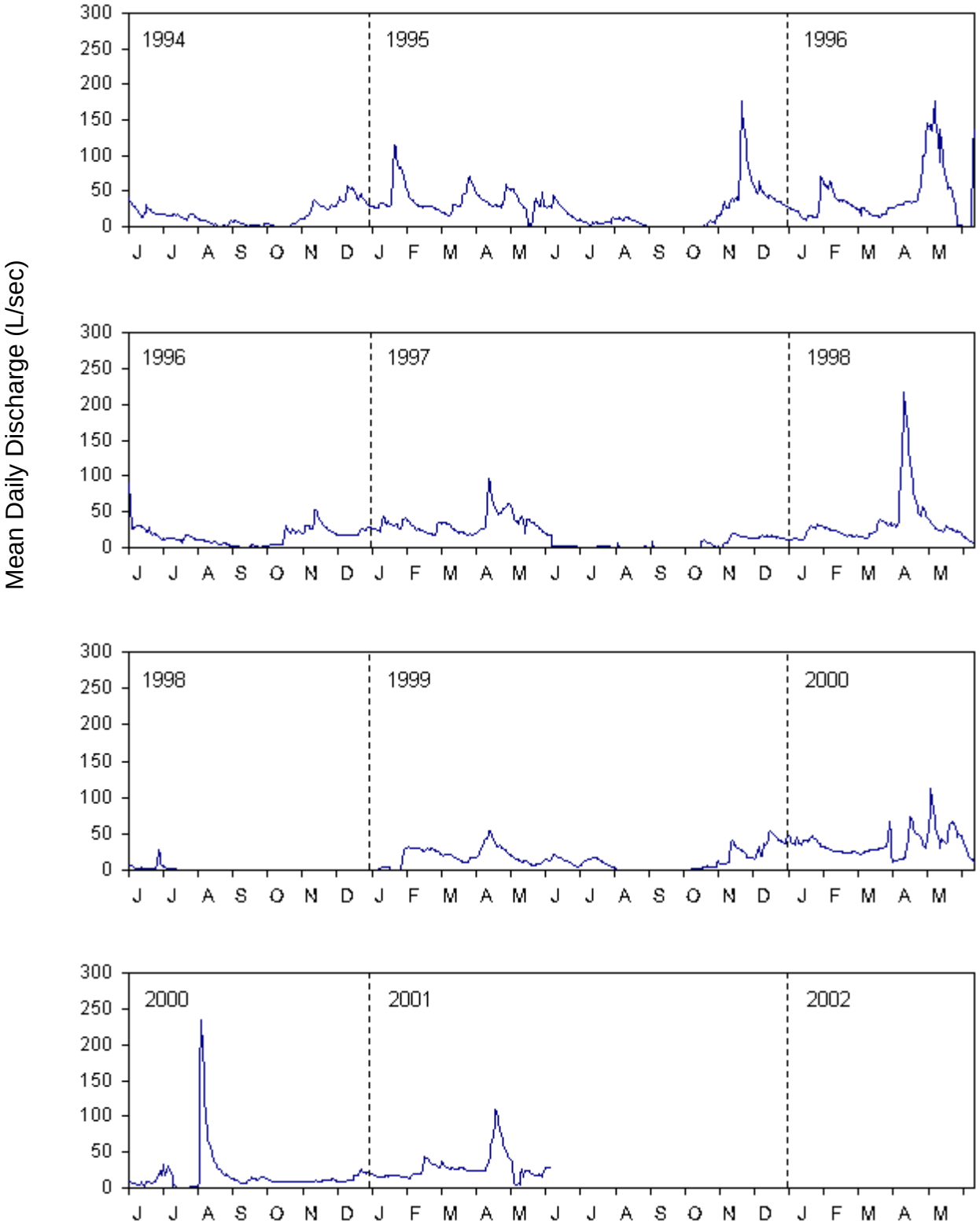
Blue Chalk Outflow Hydrograph



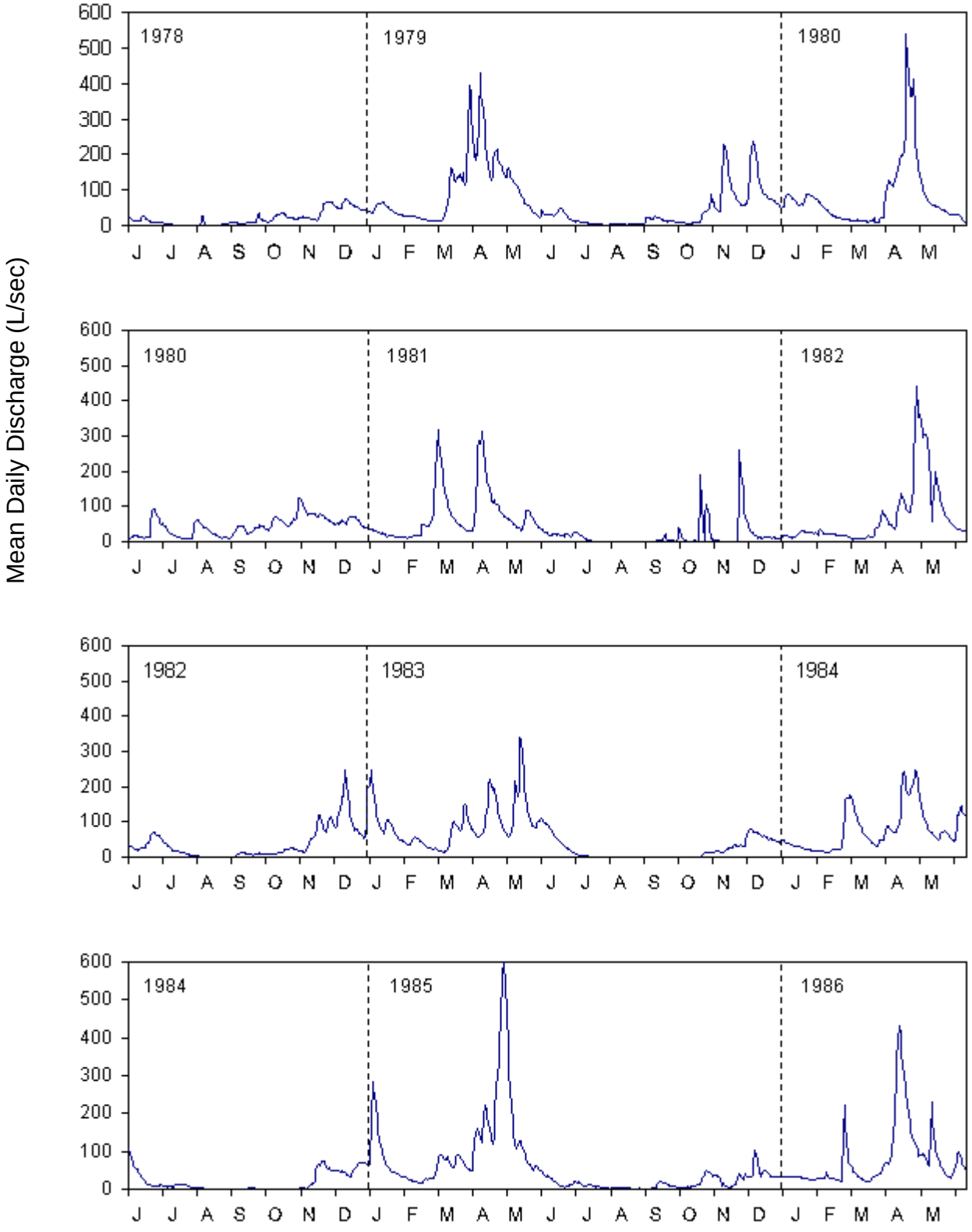
Blue Chalk Outflow Hydrograph



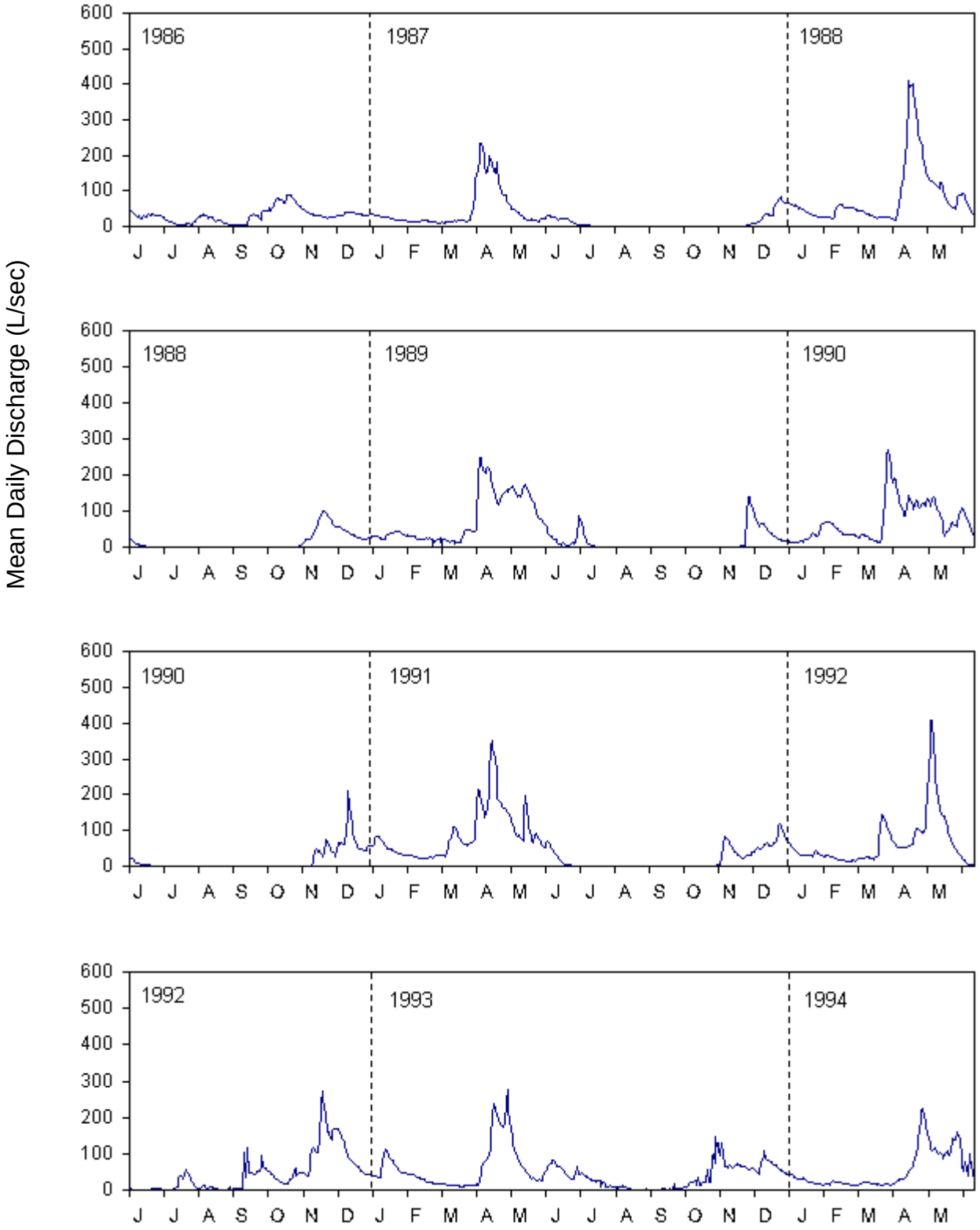
Blue Chalk Outflow Hydrograph



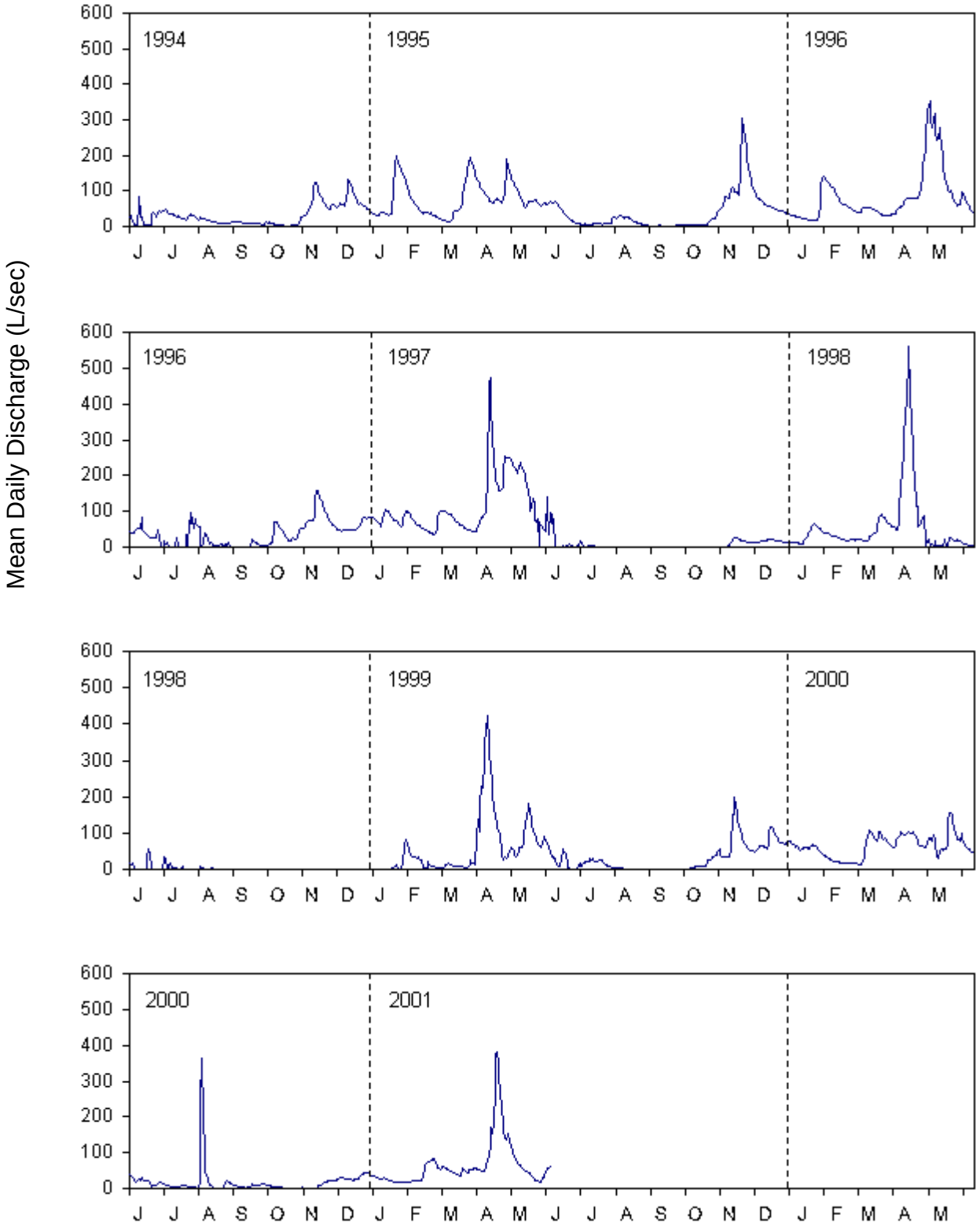
Chub Outflow Hydrograph



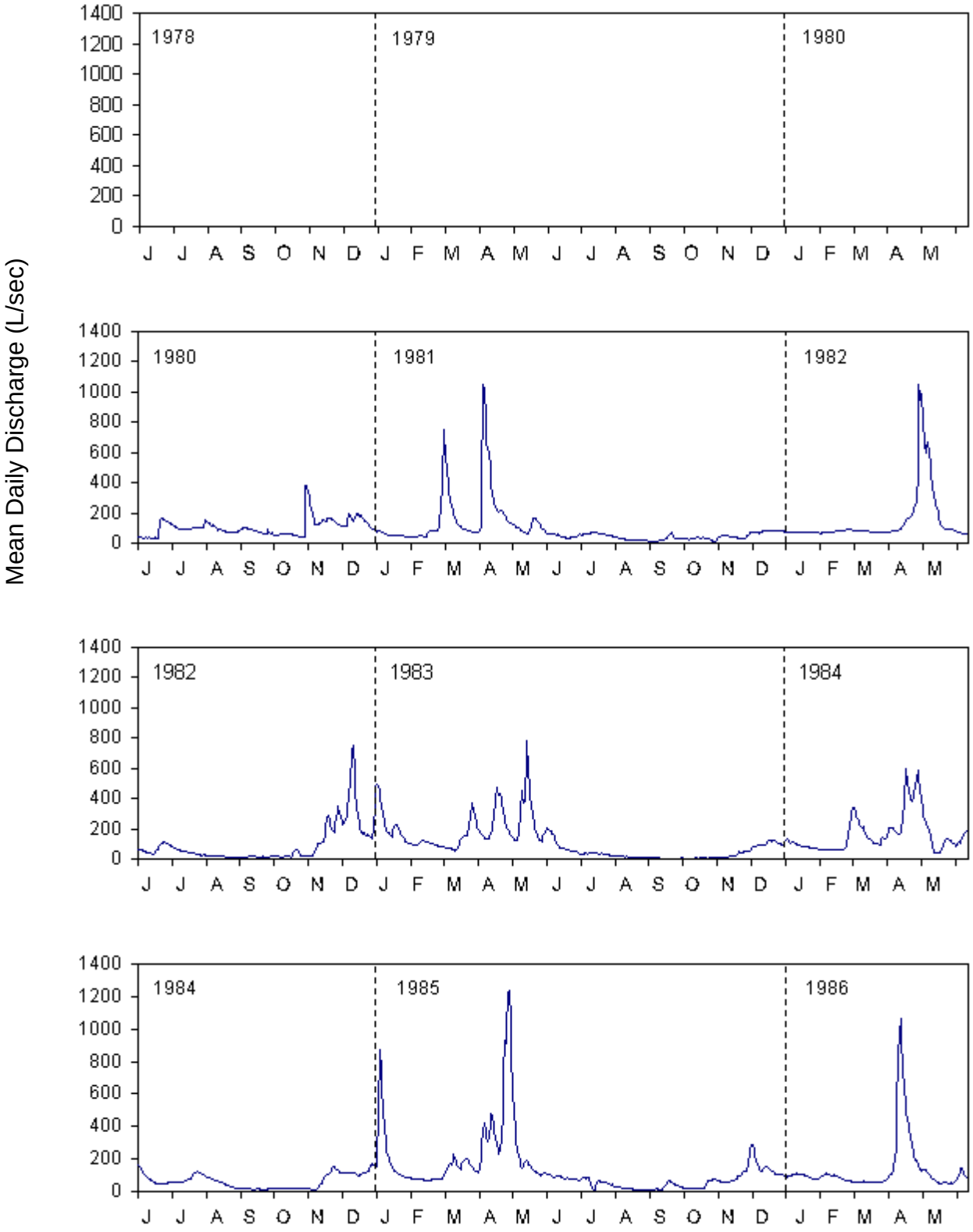
Chub Outflow Hydrograph



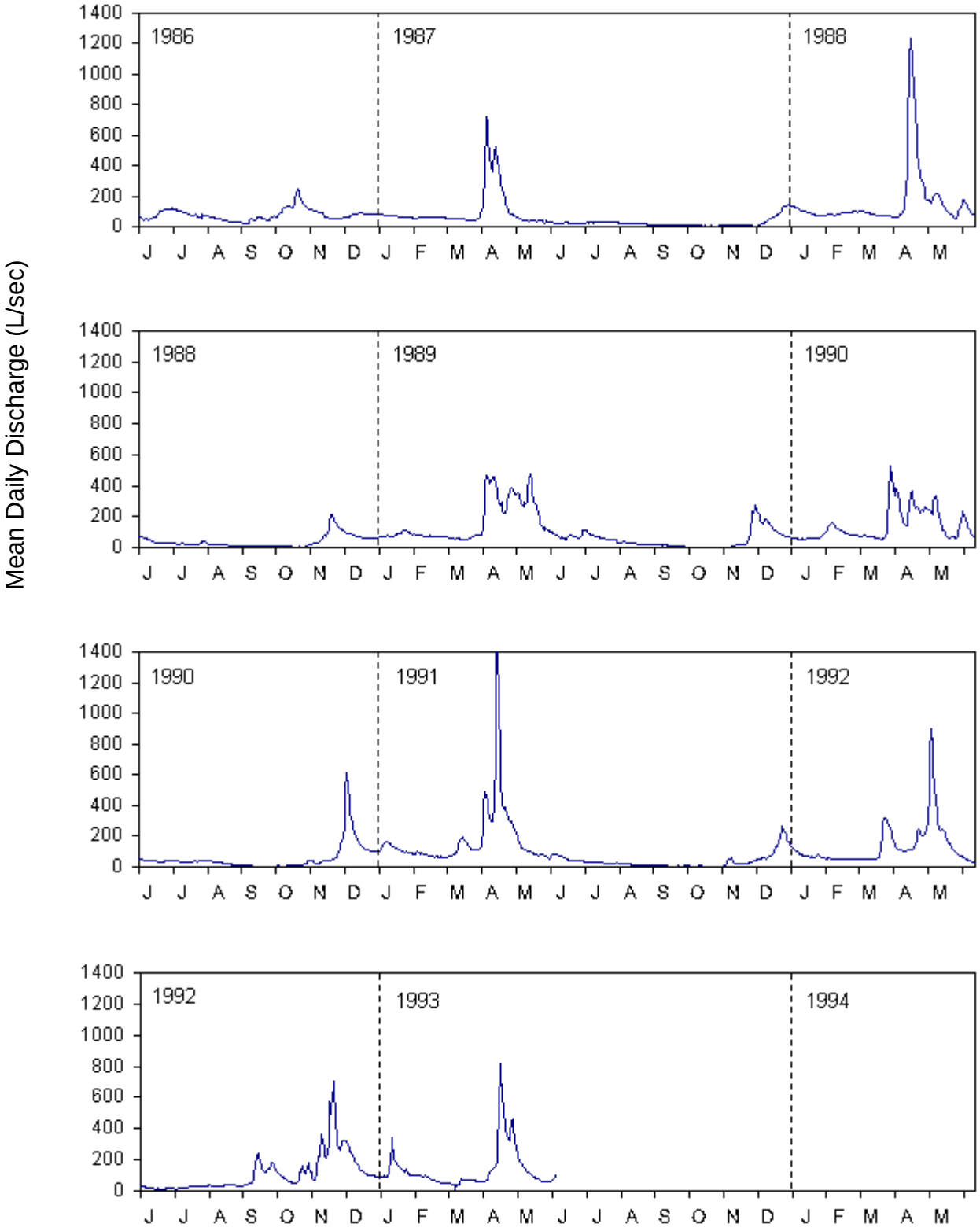
Chub Outflow Hydrograph



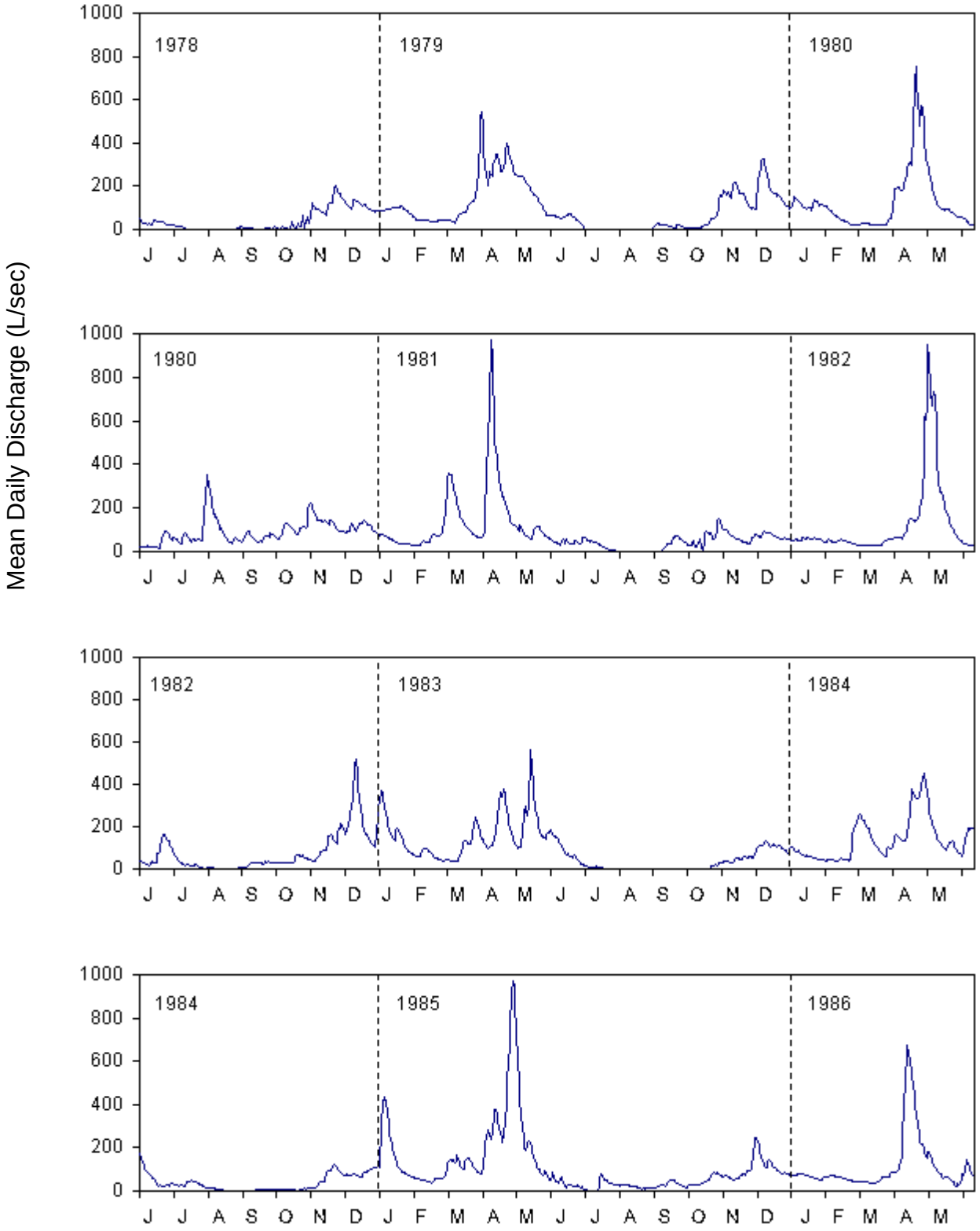
Crosson Outflow Hydrograph



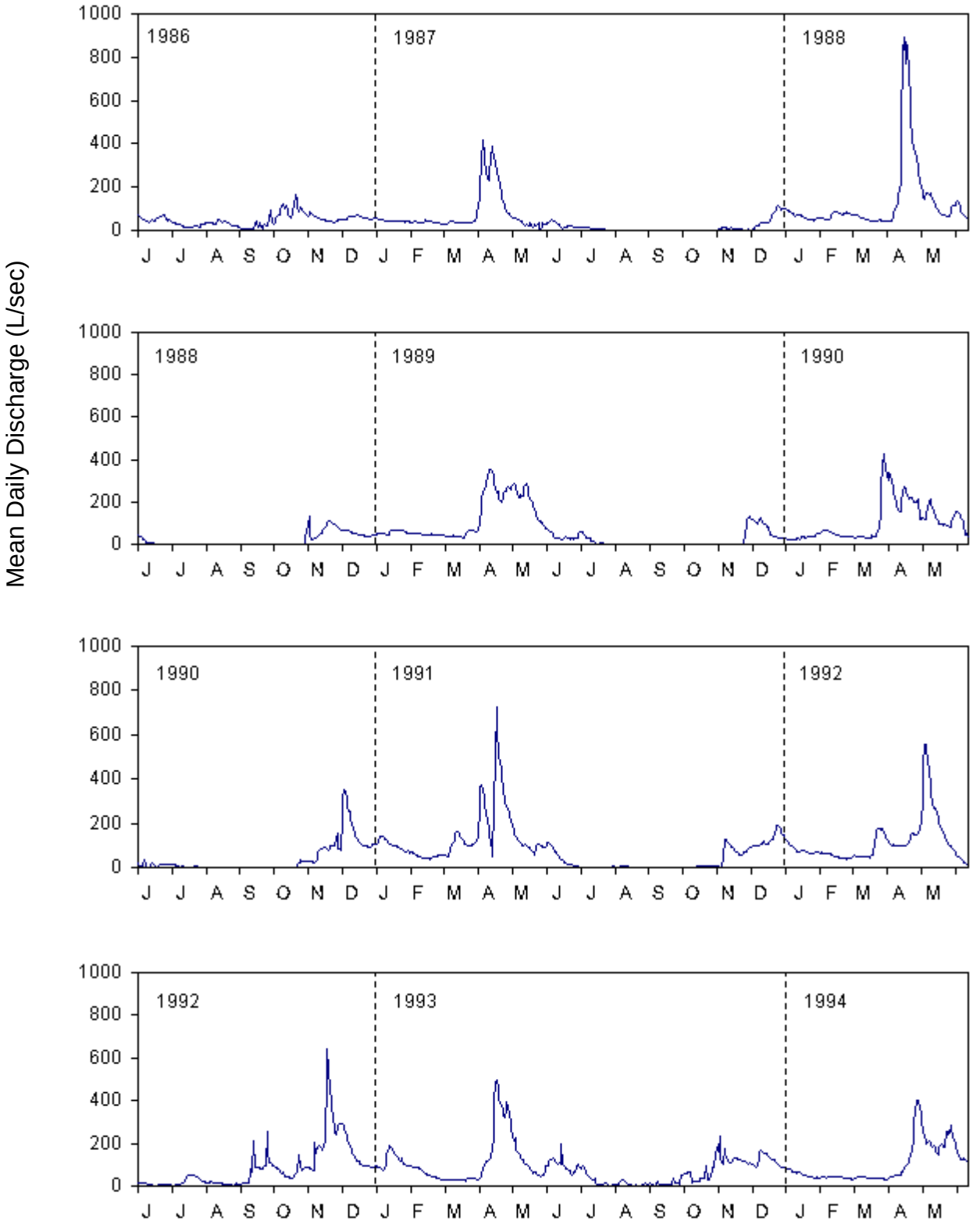
Crosson Outflow Hydrograph



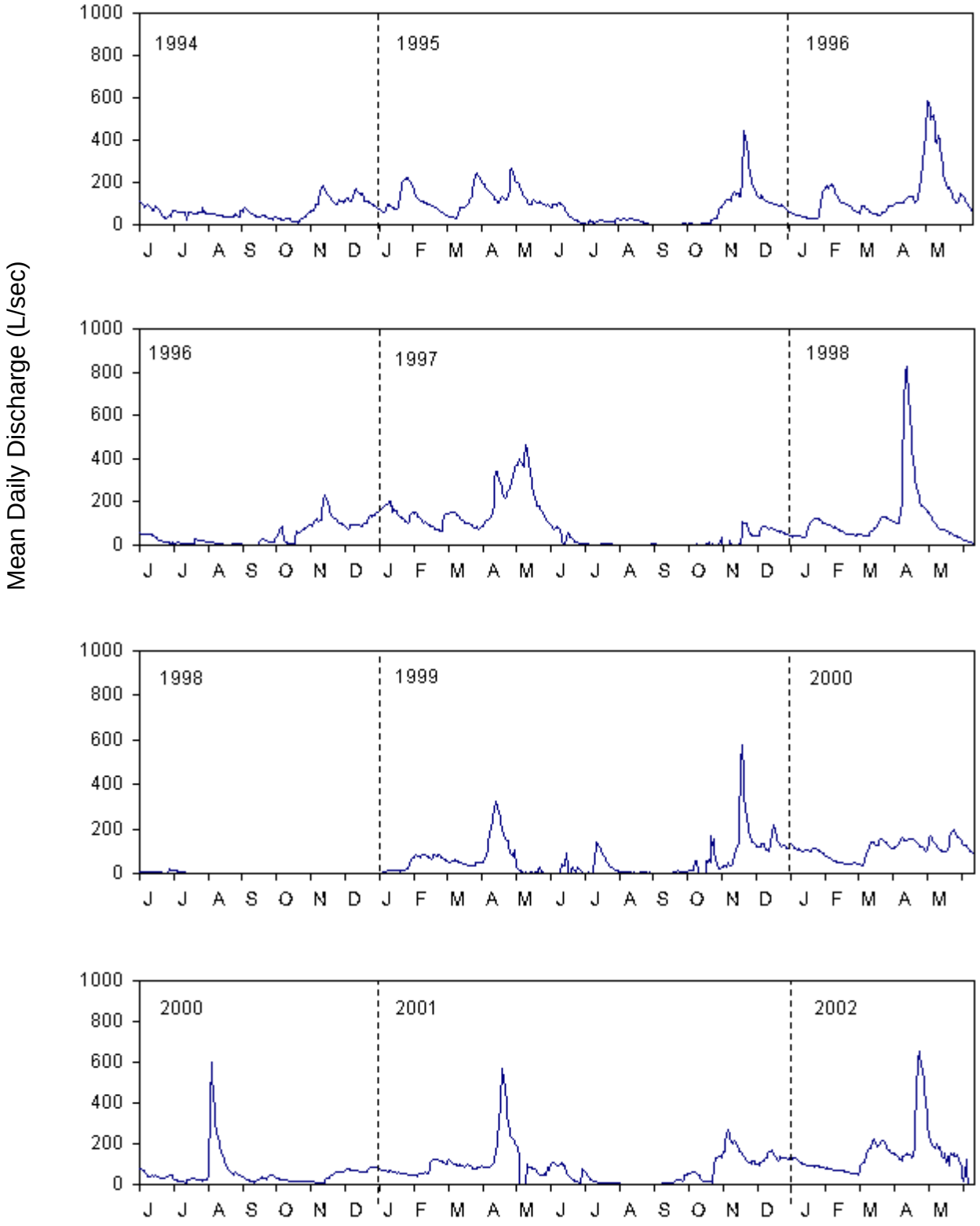
Dickie Outflow Hydrograph



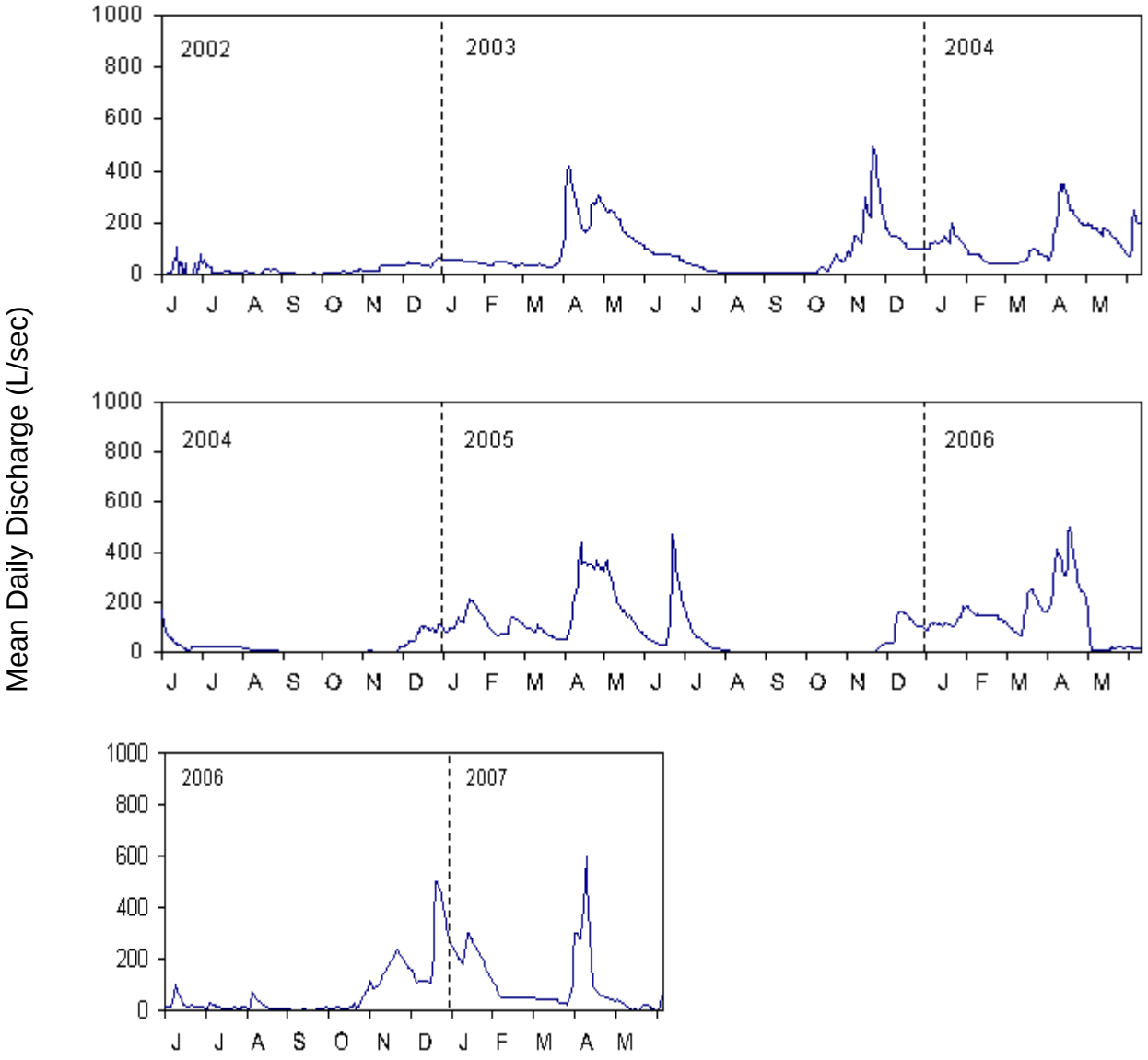
Dickie Outflow Hydrograph



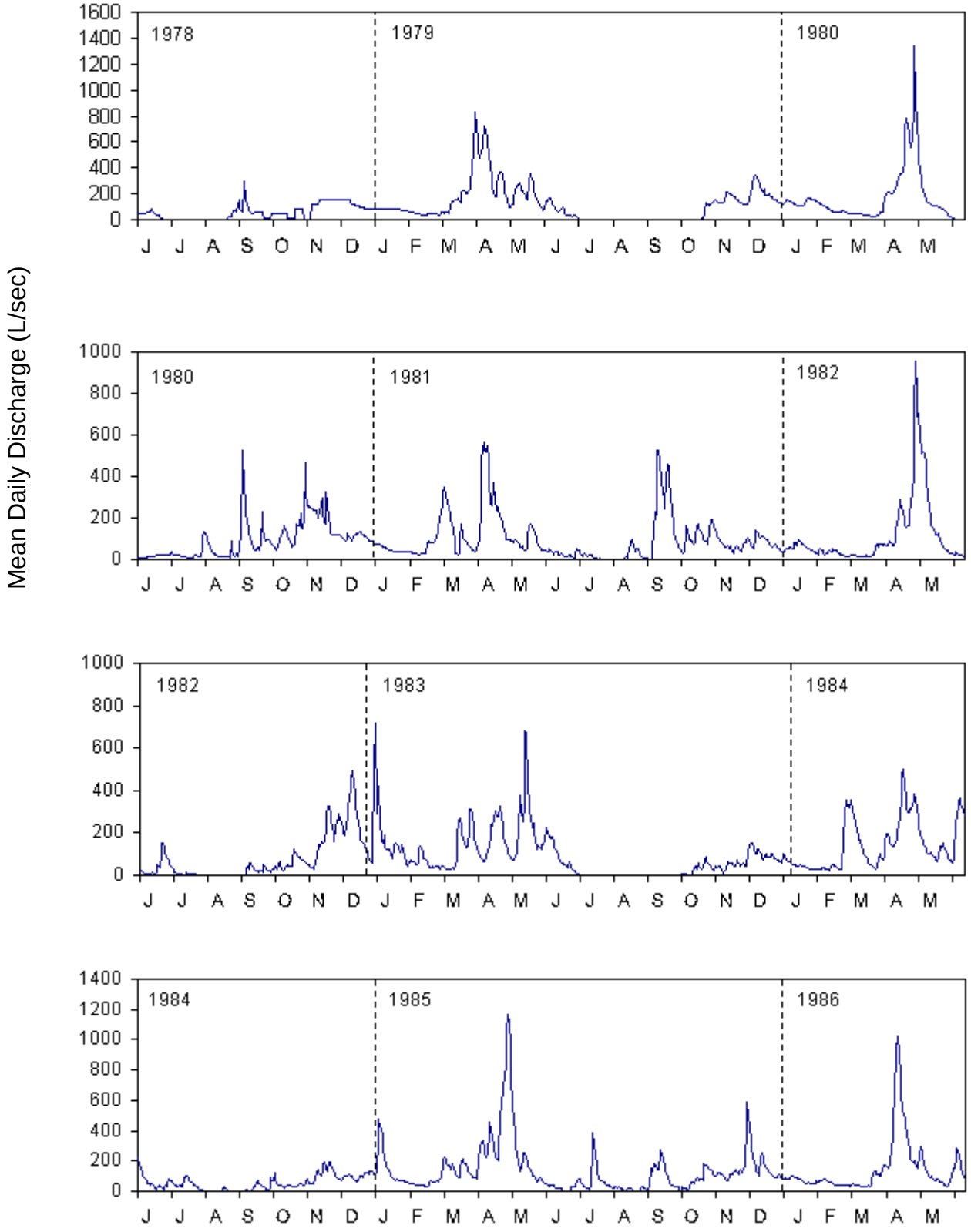
Dickie Outflow Hydrograph



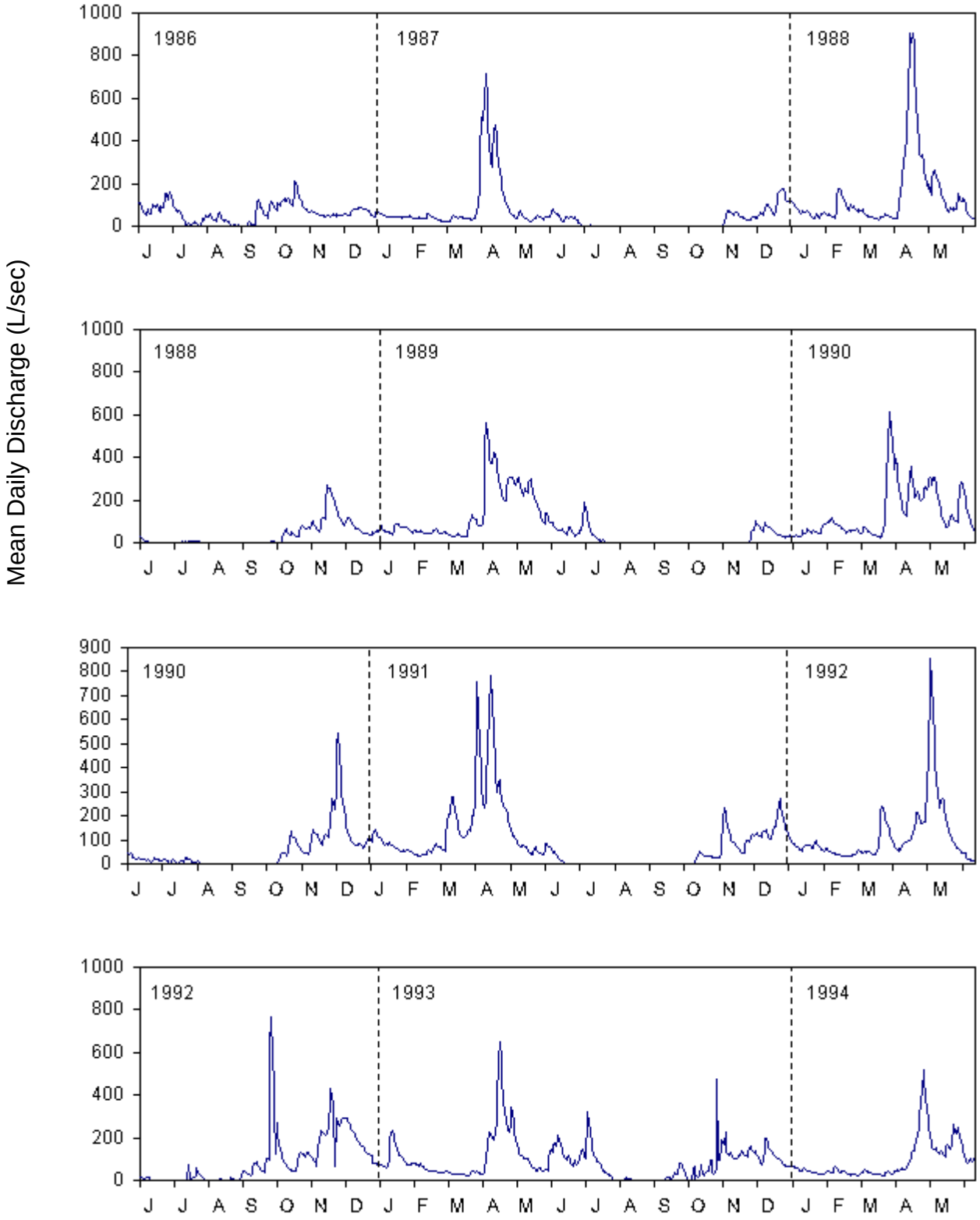
Dickie Outflow Hydrograph


Mean Daily Discharge (L/sec)
1000
800
600
400
200
0
2002
2003
2004
J J A S O N D J F M A M J J A S O N D J F M A M
2004
2005
2006
J J A S O N D J F M A M J J A S O N D J F M A M
2006
2007
J J A S O N D J F M A M

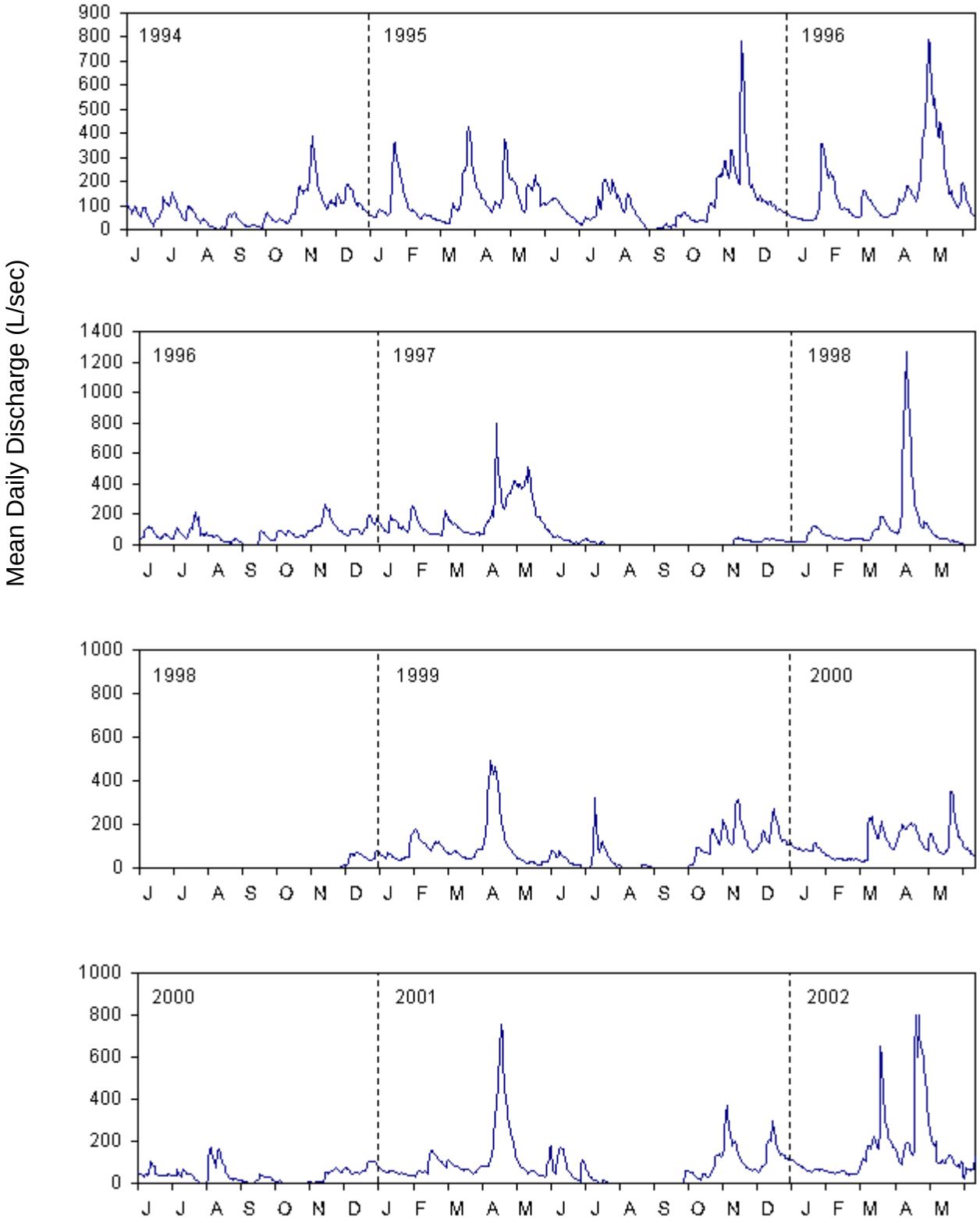
Harp Outflow Hydrograph



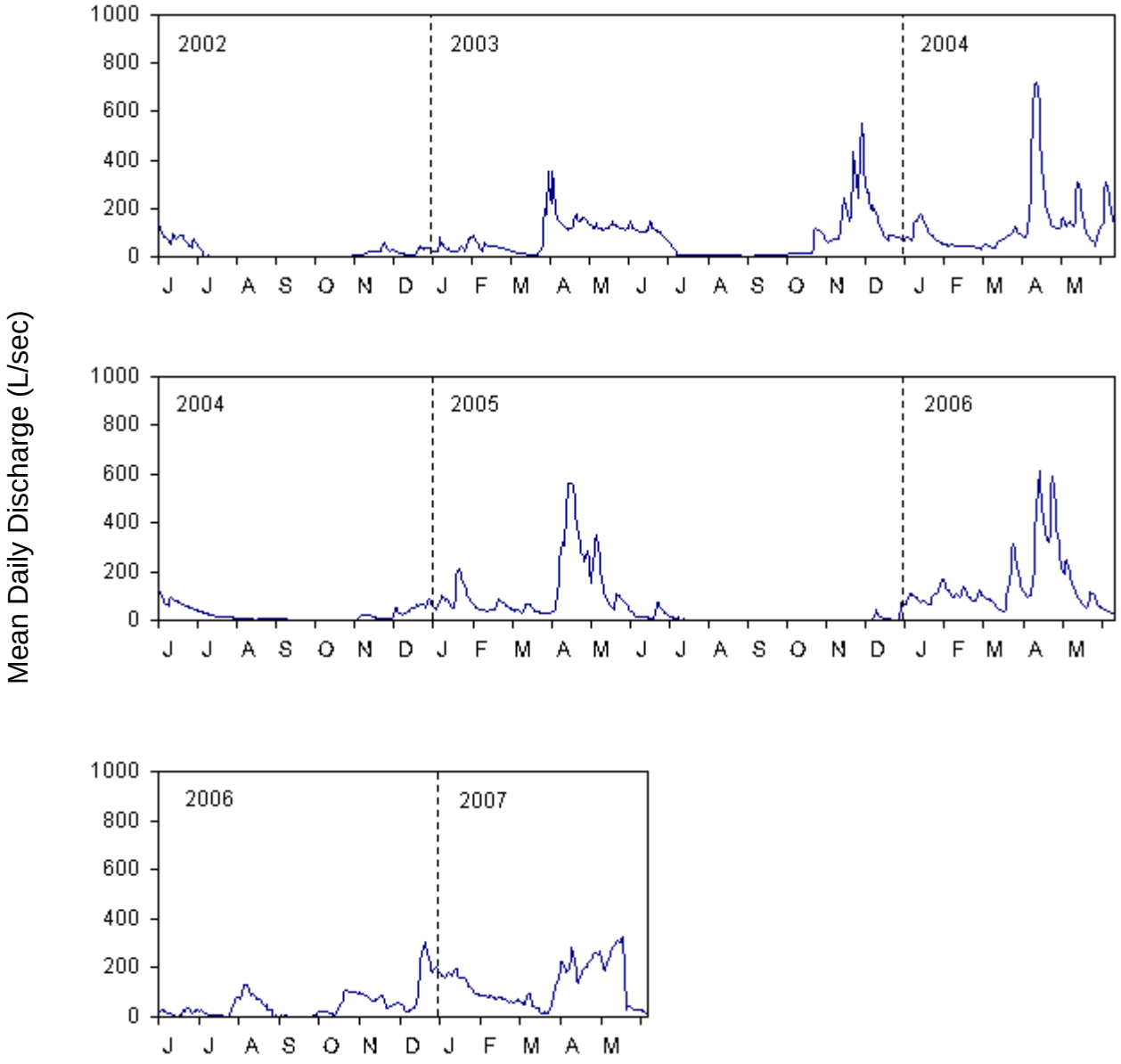
Harp Outflow Hydrograph



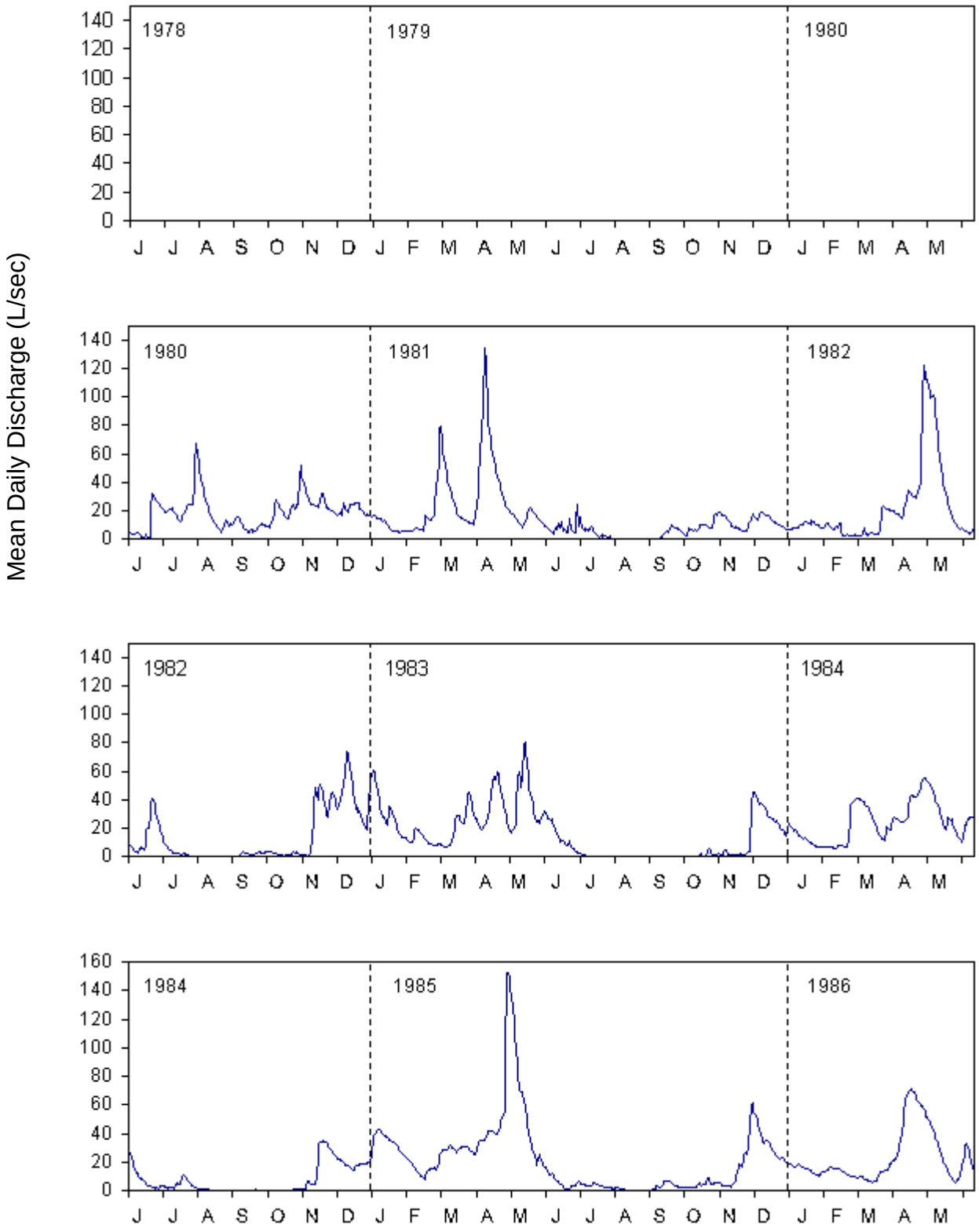
Harp Outflow Hydrograph



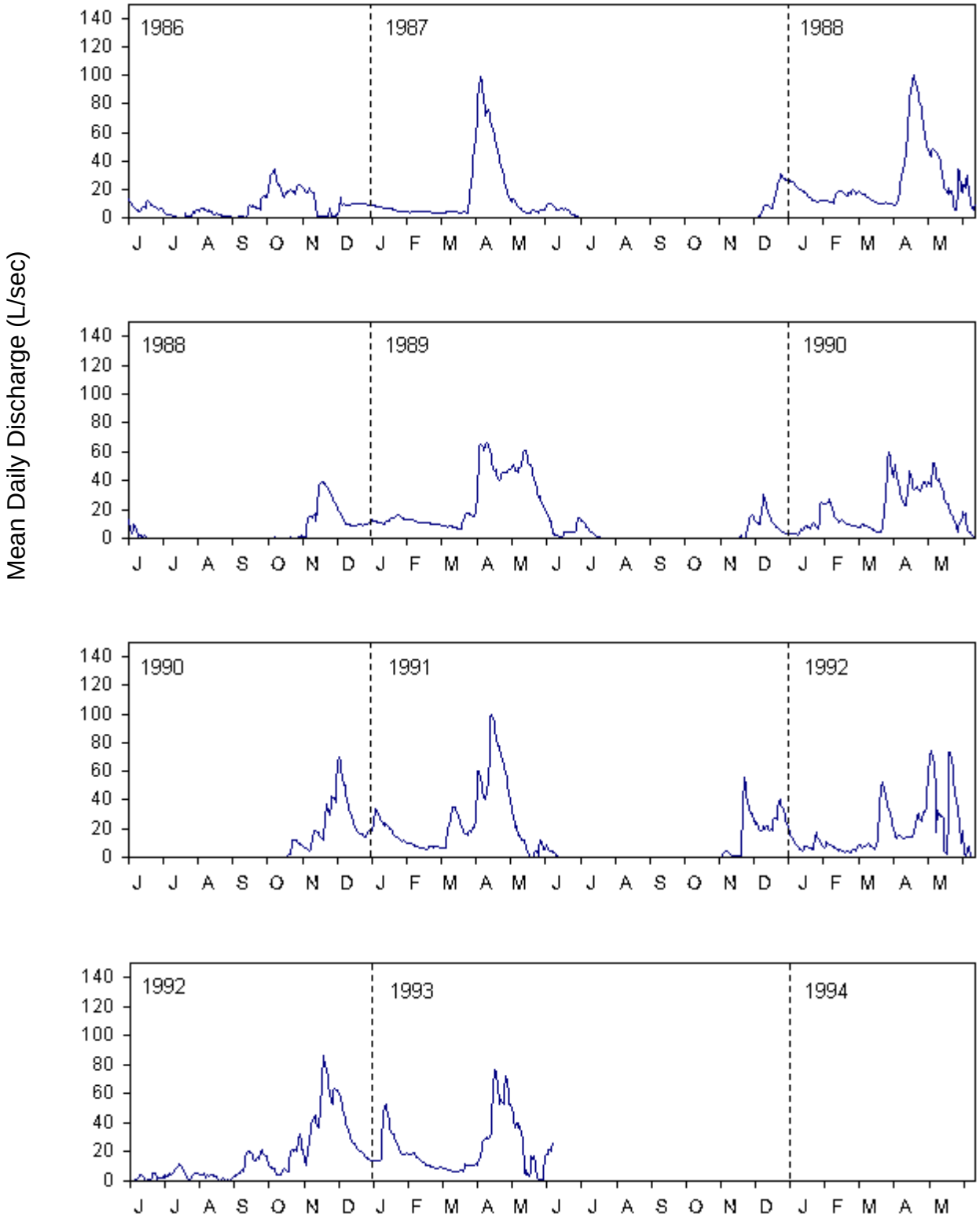
Harp Outflow Hydrograph



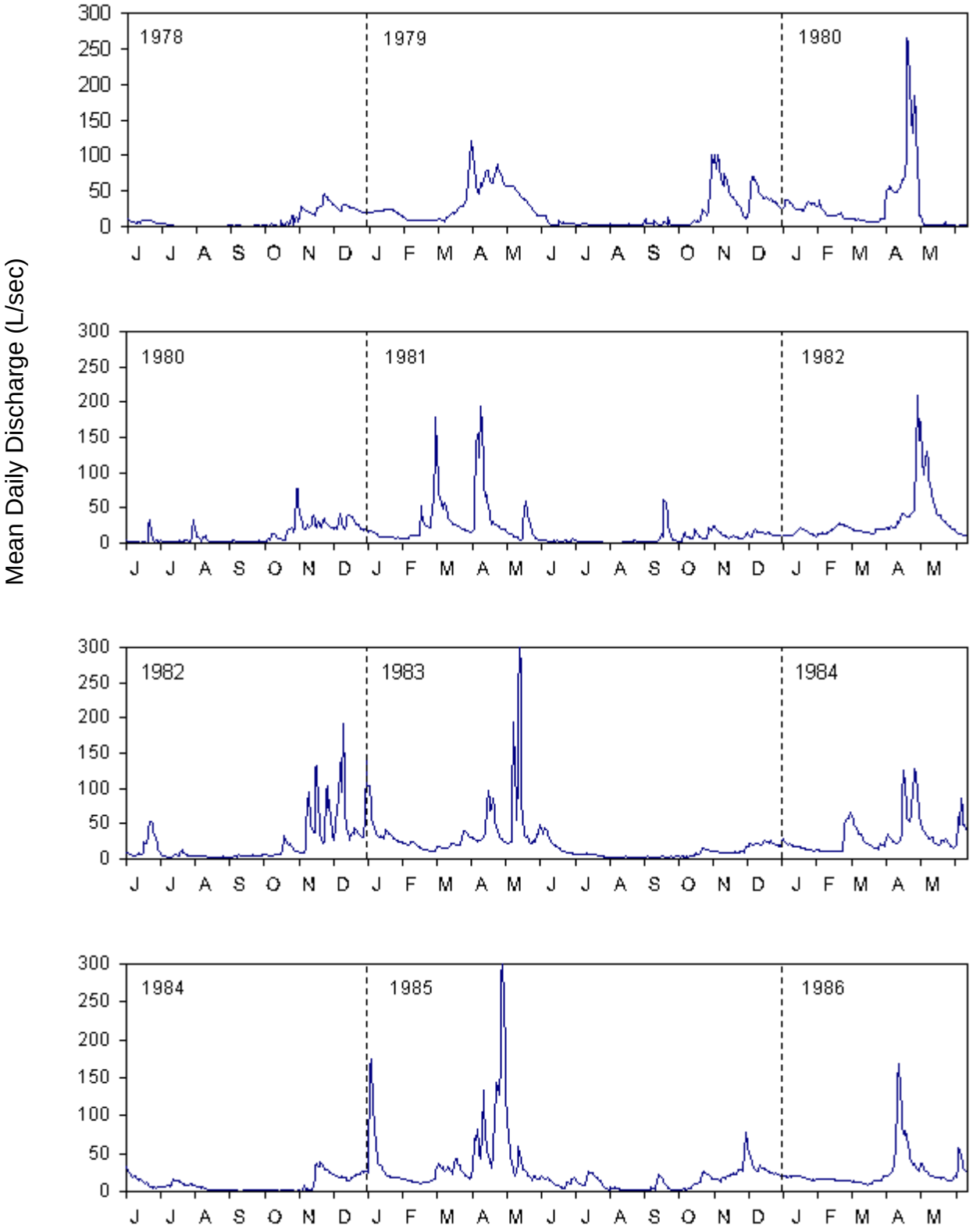
Heney Outflow Hydrograph



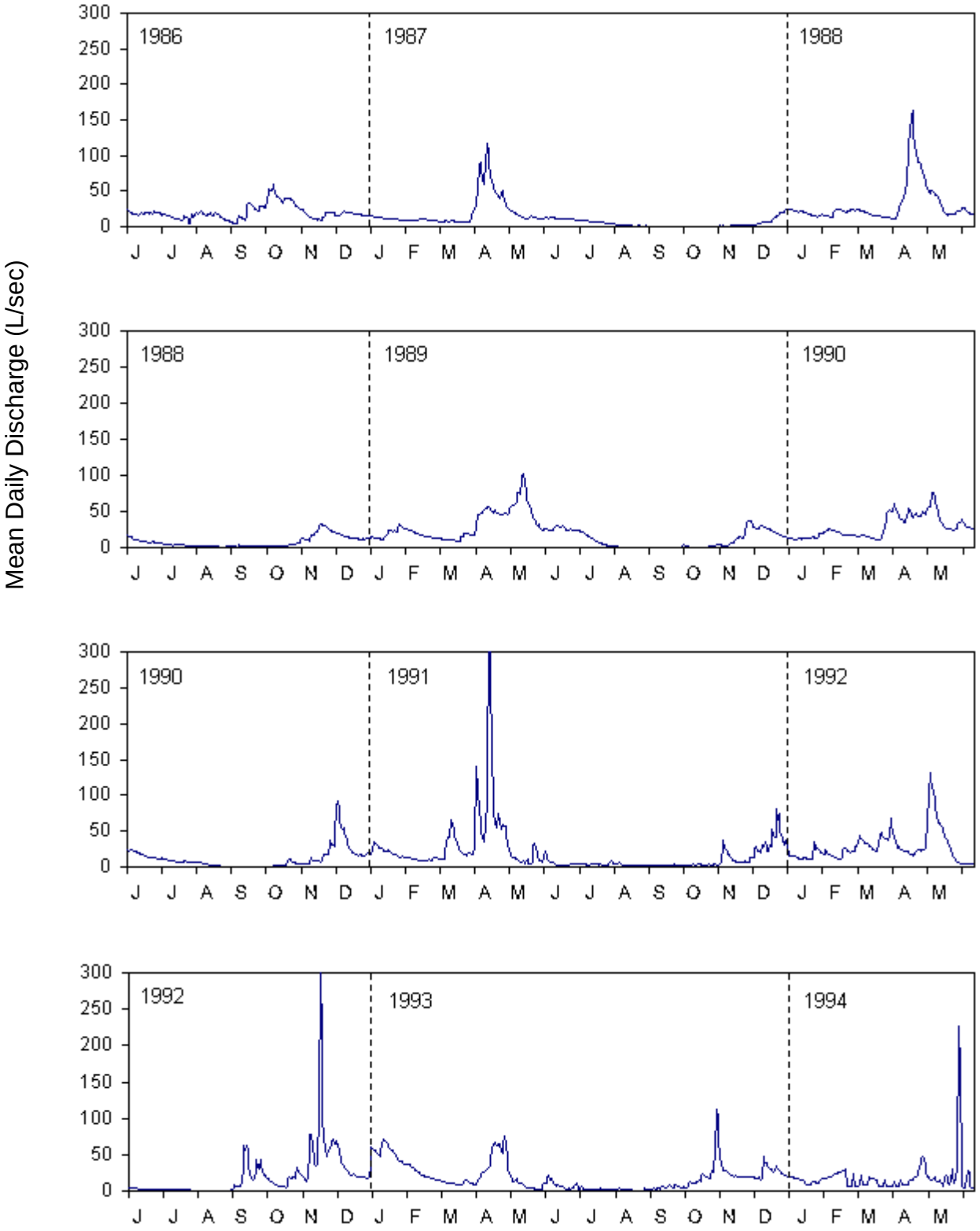
Heney Outflow Hydrograph



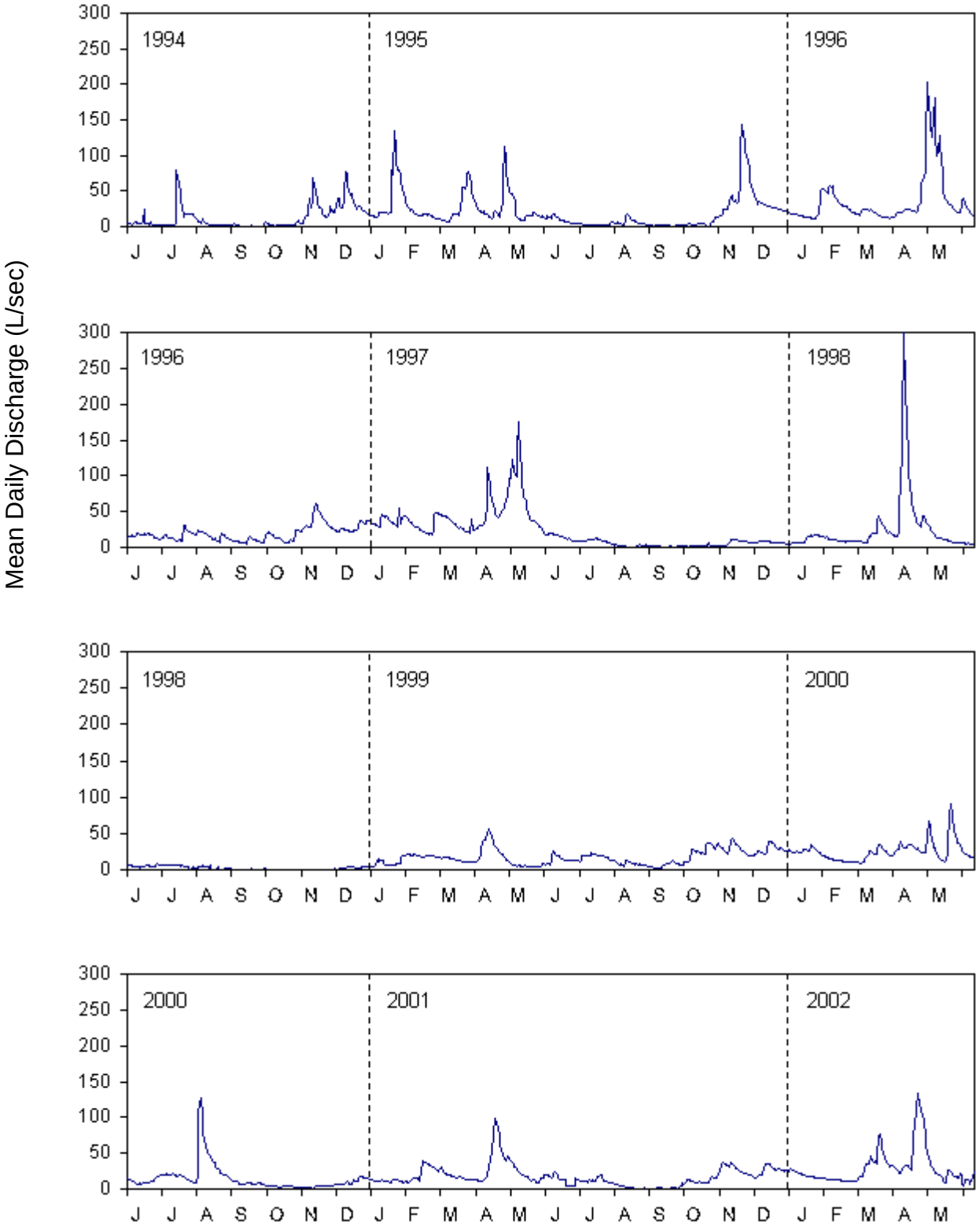
Plastic Outflow Hydrograph



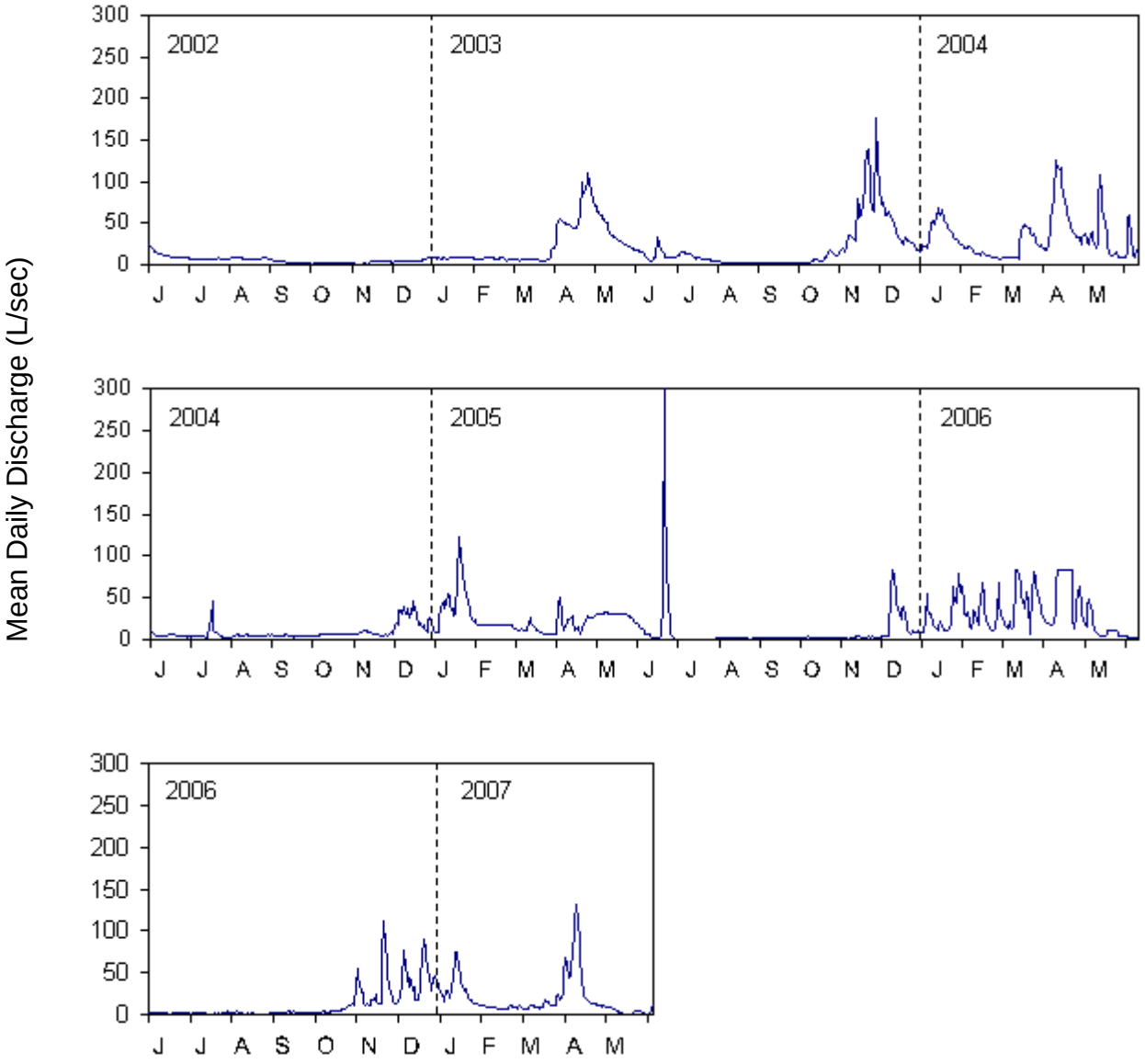
Plastic Outflow Hydrograph



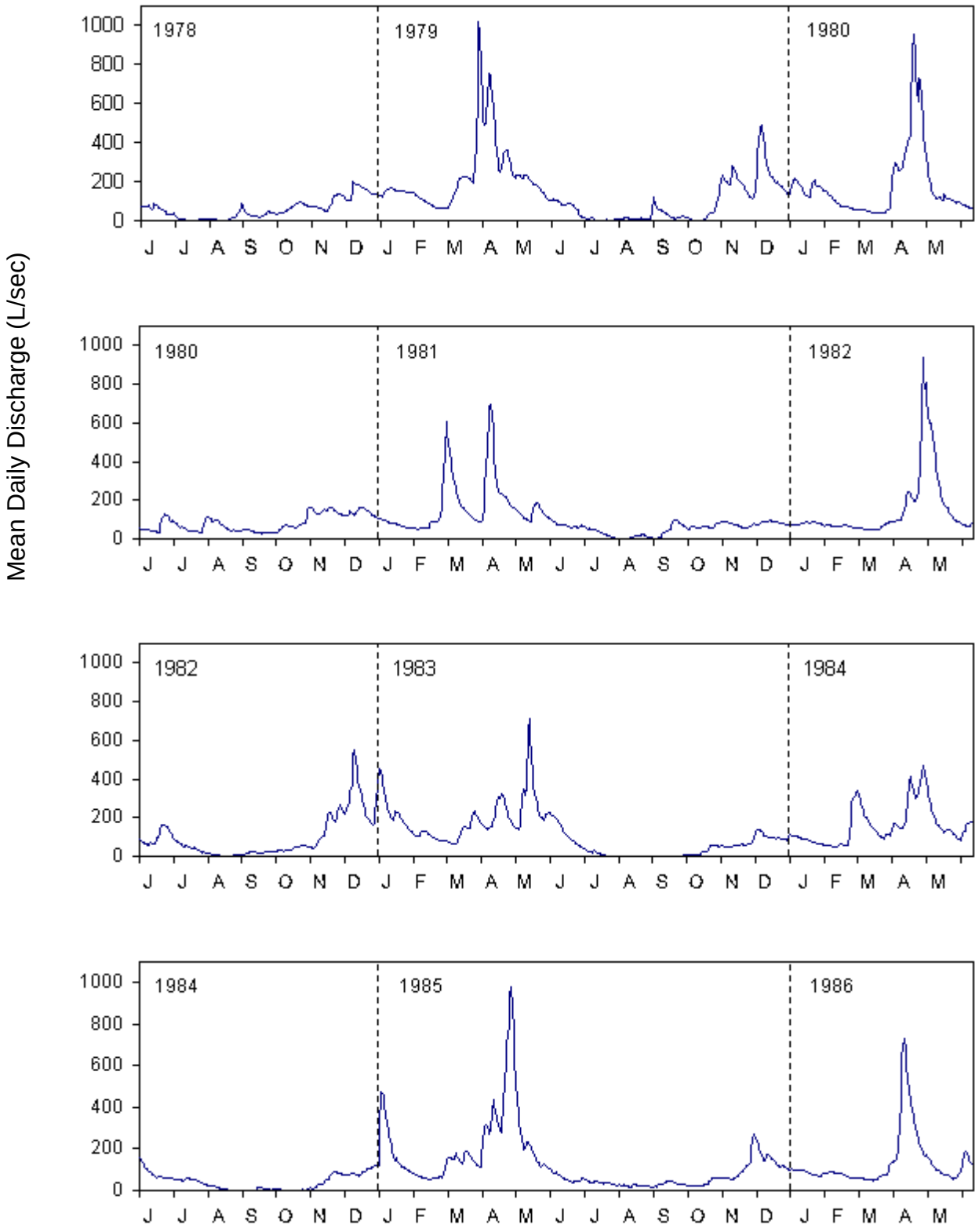
Plastic Outflow Hydrograph



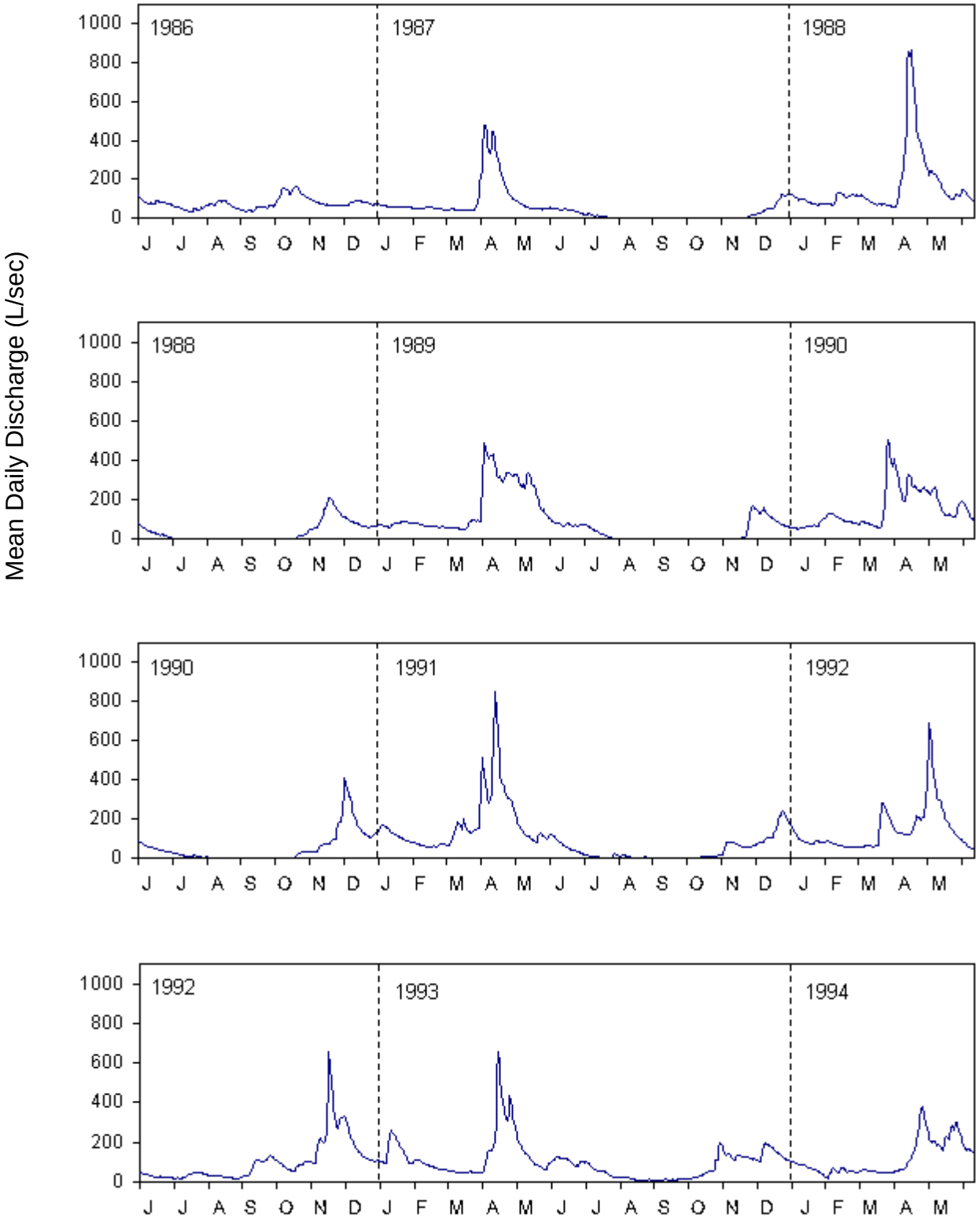
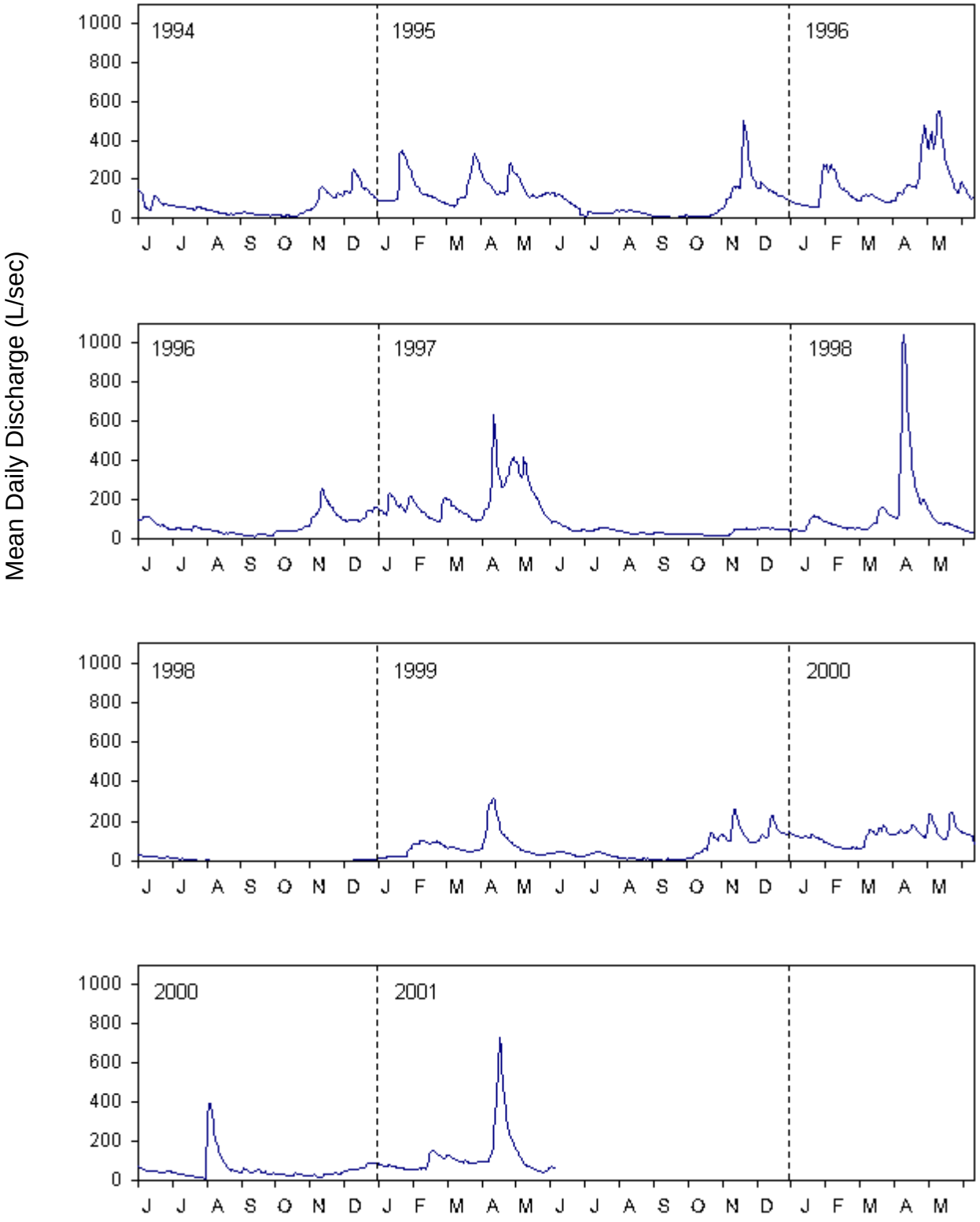
Plastic Outflow Hydrograph


Mean Daily Discharge (L/sec)
300
250
200
150
100
50
0
2002
2003
2004
J J A S O N D J F M A M J J A S O N D J F M A M
2004
2005
2006
J J A S O N D J F M A M J J A S O N D J F M A M
2006
2007
J J A S O N D J F M A M

Red Chalk Outflow Hydrograph



Red Chalk Outflow Hydrograph



Red Chalk Outflow Hydrograph